ELECTRICAL ENGINEERING

APRIL 1946

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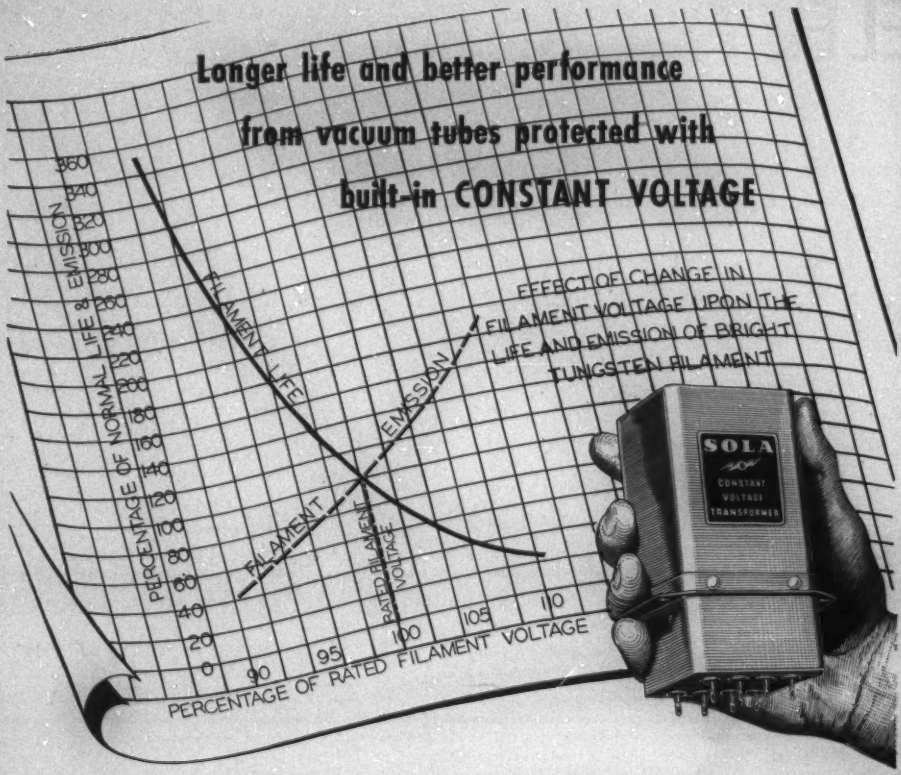

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The Cover. Five-hundred airplane Royal Air Force bomber raid as seen on off-centered PPI (plan-position indicator) of microwave ground radar; range circles ten miles apart. Wispy trail of signals at left of picture is result of "window" counter measure—tin foil strips dropped to confuse enemy radar. Effect on microwave radar is slight.

Photo courtesy Radiation Laboratory, Massachusetts Institute of Technology

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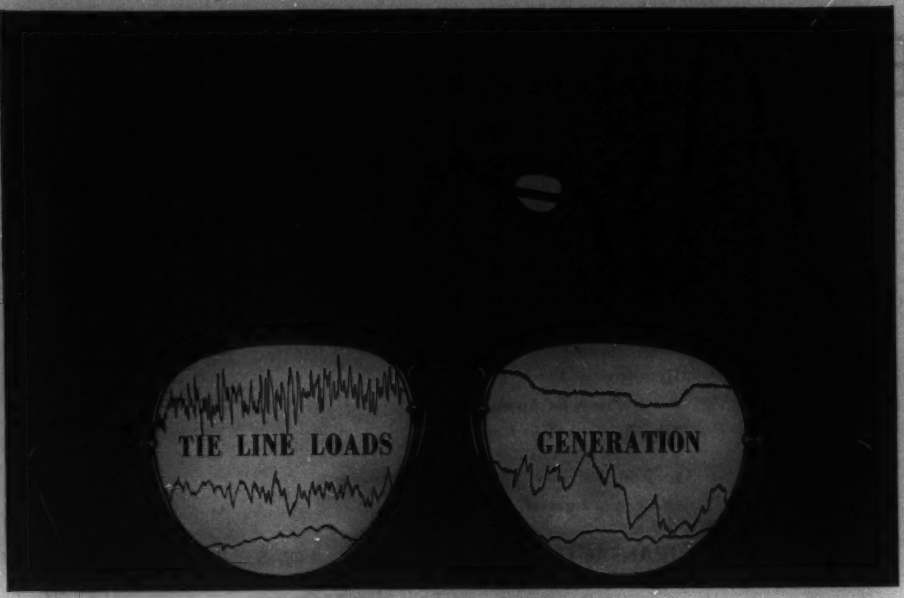

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HIGHLIGHTS.....

District Meetings. As this issue of *Electrical Engineering* reaches the membership, late as usual, the South West District meeting at San Antonio probably will be over, and the North Eastern District meeting at Buffalo immediately imminent. Next will be the Southern District meeting at Asheville; then the summer convention at Detroit. All information pertaining to the programs of these meetings, including abstracts of scheduled technical papers, has been and will continue to be published in *Electrical Engineering* as it becomes available. Reports covering these meetings, as well as general-interest material available from them, will be published in *Electrical Engineering* as soon as possible following the meetings. Most of the abstracts for the Buffalo meeting are in this issue (*pages 174–5*).

Engineering Organization. Four different plans for the possible reorganization of the engineering profession are included in the initial progress report of the professional activities subcommittee of the AIEE committee on planning and coordination, incidental to the latter's current study of ways and means of improving AIEE activities and membership services. These plans are published, not as recommendations, but to stimulate discussion at Section and District meetings, and ultimately at the forthcoming summer convention in Detroit (*pages 169–73*).

Circuit Breakers. Field tests made by the Hydro-Electric Power Commission of Ontario prove the feasibility of testing 138-kv circuit breakers on a large system provided necessary preliminary work is done to establish the generator and line arrangement required to produce and control the specified value of short circuit current (*Transactions pages 199–204*). Evolving from self-contained air circuit breakers which later were supplemented by circuit breakers operating on the principle of magnetic deionization of a single arc, the latest development is a line of magnetic air circuit breakers for ratings up to 500,000 kva and 15 kv (*Transactions pages 220–3*). To meet exacting performance requirements a new line of high-voltage outdoor tank-type oil circuit breakers incorporates improvements in the design of the interrupter, the bushing, the tank and top frame, and the operating mechanism (*Transactions pages 224–31*).

ASA in Consumer Field. A working understanding appears to have been reached between the American Standards Association and the United States Department of Commerce whereby ASA has achieved recognized standing in the field of consumer goods, subject to certain qualifications stipulated by the Department of Commerce. Accordingly, plans are well under way to expand the ASA financial structure, as well as to broaden the incidence of support and participation in the ASA (*pages 183–4*).

Research Legislation. Apparently renouncing the recommendations made by a majority of the many scientists in voluminous testimony before the Senate Committee during recent months, a new Bill, S1850, would establish precepts and procedures whereby government would have complete control not only of research, but of developments growing out of research. Competent observers view this concerted move with alarm, and believe that it is a matter of direct concern to every engineer and scientist (*pages 185–6*).

Radar. The characteristics and performance qualities of any radar system are shown to be dependent not only upon the quality of the component parts, but also upon the system planning and the nicety with which the parts are fitted together (*Transactions pages 209–15*). "Now can be told" the history and physical makeup of the Shoran radar, so effective for precision position-finding in aerial navigation and blind bombing (*Transactions pages 232–40*).

Model Law Endorsed. Action has been taken by the AIEE board of directors recognizing the registration of engineers as a continuing practice, endorsing the model law for professional engineers and land surveyors, and authorizing the establishment of a standing committee on registration of engineers. Joint Student Branches also were authorized (*pages 167–8*).

Airplane Power Plants. Two new power plants for airplanes, the gas turbine–jet propulsion engine and the gas turbine–propeller drive, are expected to play a significant role in aviation of the near future. Although it is not likely to displace the reciprocating engine in the fields of low power and low speed, the advantages of the gas turbine indicate its probable use in the higher speed ranges (*pages 180–3*).

Atomic Power. Speculation as to the potentialities of atomic energy, both as a weapon and as an industrial tool, has been widespread, with predictions that range from the ultra-conservative to the fantastic. In an attempt to clarify the situation three winter convention talks are published, giving the views of three recognized authorities (*pages 145–50*).

Inertia Throat Microphones. The theory and design of magnetic inertia throat microphones is described with special emphasis on the treatment of sound-powered and high-articulation throat microphones. These microphones have a band-pass filter character with a sharp high frequency cut-off to cut out high frequency noises (*Transactions pages 187–91*).

Polyphase Reluctance Motors. The performance calculations presented by Doherty and Nickle in 1926 in their classic paper on synchronous machines have been rearranged and simplified for the benefit of the engineer who has occasion to design small reluctance motors (synchronous motors without field excitation) (*Transactions pages 191–3*).

Westinghouse Centennial. Initiating a series of activities planned to honor the centennial of the birth of George Westinghouse, the American Society of Mechanical Engineers recently sponsored a dinner at the Engineers Club in New York (*pages 189–90*).

Variable Ratio Transmission. An electric governor is described that is intended to provide the automatic control required for parallel operation of electric generators in large aircraft which involve heavy consumption of electric power and wide ranges in engine speeds (*Transactions pages 194–8*).

Thin Permalloy Tape. With the increasing need for efficient magnetic structures at high frequencies, such as pulse transformers for radar, thin permalloy tape has been developed which may be insulated and formed into cores in a continuous operation (*Transactions pages 177–83*).

Societies' Librarian Retires. For 29 years the guiding mainspring of the Engineering Societies Library in New York, Doctor Harrison W. Craver recently turned over his office to Ralph H. Phelps (*page 189*).

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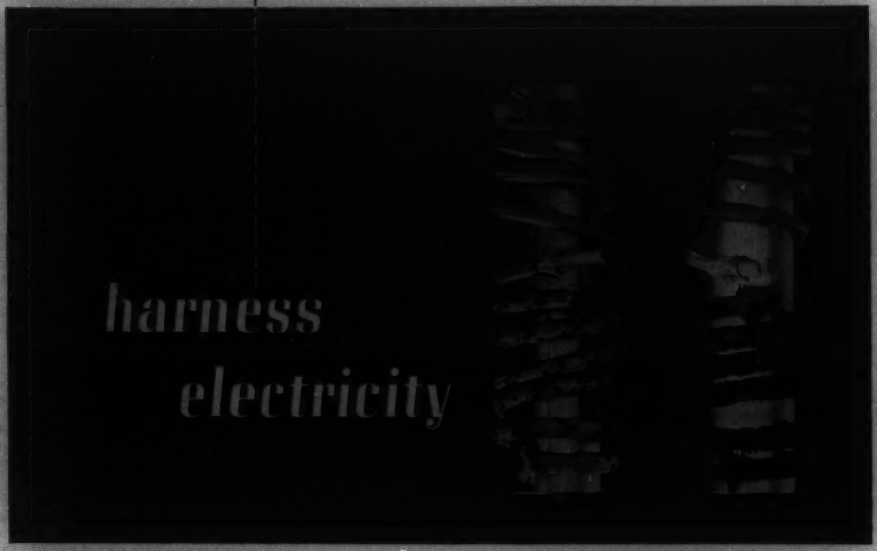

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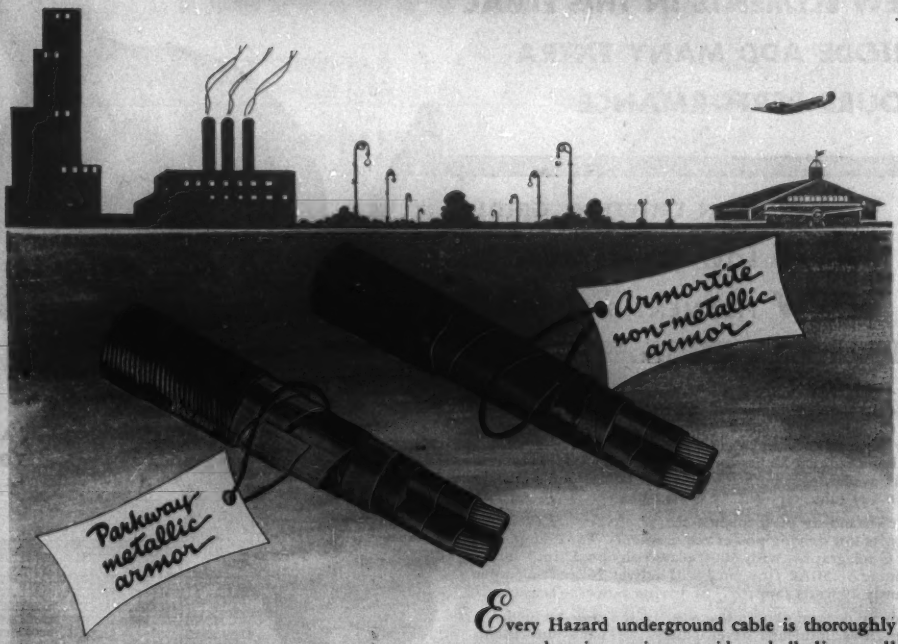

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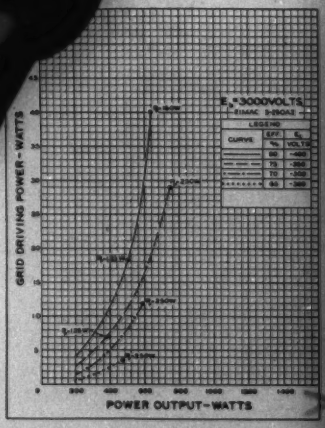

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Atomic Power in a Peacetime Economy

PROGRESS in nuclear research was reviewed in *Electrical Engineering* for March. In cognizance of the fact that atomic energy may be potentially as valuable an instrument of peace as it was of war, the following supplemental articles are presented, reflecting the views of recognized authorities concerning the role of atomic power in the postwar world, with particular emphasis on possible applications and the economics involved. The articles are based on addresses prepared by C. G. Suits (M '41) vice-president and director, research laboratory, General Electric Company, Schenectady, N. Y., Philip W. Swain, editor, *Power*, McGraw-Hill Publishing Company, Inc., New York, N. Y., and J. A. Hutcheson, associate director, research laboratories, Westinghouse Electric Corporation, East Pittsburgh, Pa., for the symposium on nuclear energy held during the recent AIEE winter convention in New York.

I. Peacetime Uses of Atomic Energy

C. G. SUITS

SINCE AUGUST 6, 1945, there has been much speculation about peacetime uses of atomic, or nuclear, energy. The proposed uses range from automotive power plants, through ship propulsion, to interplanetary rockets. If one weights all of the doubtful physical and chemical factors heavily on the optimistic side, and neglects the economic factors completely, very few of these applications can be ruled out entirely. Which of these possible applications of nuclear energy is likely to become practical, and when, depends upon the amount of research, development, and engineering effort which can be devoted to these physical factors in the immediate future. The object of this article is to consider some of the possible applications of nuclear energy, to illustrate what steps must be taken, primarily in research, to bring them into reality.

REVIEW OF BASIC FACTS

That energy may be produced by the disintegration of the nucleus is not new. That fact has been known since the discovery of natural radioactivity 50 years ago by Becquerel. Many years ago, one could get a very large number of kilowatt-hours per pound from radium. A pound of radium makes a miniature atomic power plant that runs for a long time at the rate of about 1/10 kw. The difficulty was that radium did not then, and does not now, come by the pound but rather by the milligram at a price of $20 per milligram. In 1939 a new type of nuclear disintegration called fission was discovered to occur in uranium, thorium, and some other elements. Of these, in comparison with radium, uranium is relatively abundant and may be bought by the pound at a cost of a few dollars. However, in uranium only the isotope U-235 undergoes fission. This isotope is present as less than one per cent of the natural material, although, under the most favorable circumstances, the bulk of natural uranium, suitably purified, may be converted to fissionable elements so that nearly all of it may be used to create nuclear energy. The fission of one pound of U-235 produces 10 million kilowatt-hours.

Uranium in a pure condition, or enriched in the isotope U-235, may be used in a chain reacting pile to produce controllable heat energy. This nuclear reaction in a pile is obtained at any temperature permitted by the materials of construction which include the fissionable elements, the moderators or slower-downers, the heat transfer medium, the various mechanical parts required for control, and, finally, the radiation shield. During operation the fissionable material is used up slowly and nuclear reaction products, some of them toxic, accumulate. This means that operating personnel must be shielded from very intense radiation, especially neutron radiation accompanying the reaction. Because of a surface-to-volume effect, the pile must contain a certain minimum quantity of fissionable material to react satisfactorily. The whole mechanical assembly required for a chain reacting pile, and some of the problems of operation, become analogous to a stoker-fired boiler. The fissionable material or fuel must be fed in, the reaction products or ashes must be removed, and the mechanical parts must tolerate the radiation and temperature stresses.

Confining the penetrating radiation of the pile is a far more serious matter than confining the steam or mercury vapor in a typical boiler. The shielding for this purpose must be equivalent to several feet of steel, and there is little prospect that this will be reduced in the typical case. For this reason small fission power plants appear to be out of the question at present as a minimum size of approximately 50 tons is required.

Let us consider the economy of a chain reacting pile as a heat energy source. The fission energy in one pound of U-235 equals the heat energy in 1,000 tons of coal but plants for the production of uranium and element 94 are expensive to build and operate. According to General Leslie R. Groves, the United States Government's investment at Oak Ridge, Tenn., and Hanford, Wash., totaled

1.3 billion dollars with an annual operating cost of 258 million dollars. He did not state how much fissionable material is produced in these plants. Because U-235 and the other high purity materials of a pile are very expensive, because the pile structure and its auxiliaries are expensive, and because of the required skilled personnel, heat from a pile cannot compete yet with heat from a device which burns conventional fuels.

PROSPECTIVE APPLICATIONS

With the foregoing facts as a basis, some prospective applications of nuclear energy, that is, of chain reacting piles, may be considered. The fact that these piles must be large immediately precludes a host of low power applications. Automotive power is out. Railroad locomotive power is almost certainly out. Large ship propulsion seems not only possible, but attractive, though on a strategic rather than a competitive basis. An advantage gained in the space required for fuel is offset partly by the space required for shielding. Evidently a detailed research and engineering study will be required to evaluate this application. Perhaps large electric power plants are practicable in areas, Australia for example, where there is practically no conventional fuel but abundant natural resources of many other types. Atomic power plants for electric power generation probably, at some time in the distant future, will compete successfully with coal, oil, and water power energized plants. In fact, this ultimate possibility is an important hedge against long-range exhaustion of the natural oil and coal reserves. However, it should be borne in mind that there is nothing in the present status of nuclear research to justify the hope of direct conversion of nuclear to electrical energy and so this competition with conventional fuel, as far as is known today, must be evaluated from a consideration of heat production as a step in the conversion cycle.

In a typical modern steam plant, the cost of generating electric power may be made up of the following items, which, of course, do not include transmission and distribution costs:

	Costs in Cents per Kwh
Fuel	0.25
Plant investment	0.25
Plant operation	0.1
Other	0.1
	0.7

It is clear that a reduction in the cost of fuel to zero, as in the case of the free potential energy in a water power generating plant, will provide some, but not a spectacular, reduction in the cost of electric power, as the many other factors which enter into the cost of power delivered to the consumer will remain unchanged.

NUCLEAR ENERGY ON A COMPETITIVE BASIS

What must be done to make nuclear energy successively more competitive with conventional fuels? The required steps are very clear, and are primarily research steps. The basic problems of isotope separation must be studied. The physical and chemical reactions of the pile must be studied exhaustively with heat production, rather than bomb materials, as the objective. The host of serious metallurgical problems associated with the strength, durability, and radiation properties of alloys under intense neutron flux must be solved. The health and protection problem must be systematized and simplified. Finally, and most important, basic scientific knowledge must be reduced to engineering practice. This all requires a comprehensive research-development-engineering approach with long-range objectives.

Development programs directed toward the use of nuclear energy for power production should be undertaken by all branches of the power industry, probably with governmental support, but not in anticipation of quick application in competition with conventional fuels. A large amount of fundamental research in nuclear and related fields also will have to be done in support of the long-range program. As much of the equipment required in nuclear research, such as cyclotrons and betatrons, is large and expensive, it will be necessary for the government to support the fundamental program too, if it is to progress at an adequate rate.

During the war, the United States largely used up its accumulated surplus of basic knowledge of the nucleus. The dividend was the atomic bomb. Without further delay, this surplus must be restored in preparation for the important peacetime job for the nucleus—power production.

The development of economic atomic power is not a simple extrapolation of knowledge gained during work on the atomic bomb. It is a new and difficult project and great effort will be required to reach a satisfactory answer. Needless to say, it is vital that atomic policy legislation now being considered by the Congress of the United States recognizes the essential nature of this peacetime job, and that it not only permits but encourages the co-operative research-engineering effort of industrial, government, and university laboratories for this task.

Every scientist knows that the sure way to court trouble is to predict the scientific future. Bold predictions usually fall short of realization. For that reason, which can be illustrated by many examples, it is doubtful if anyone clearly foresees the potentialities of the nucleus.

In the immediate future the techniques and materials of nuclear reactions will be a tremendous stimulus to research in physics, chemistry, metallurgy, and the biological sciences. It is questionable, however, if these things, as important as they are, can be compared in importance with the ultimate possibilities of nuclear

power. The outline of this atomic age of the future is perceived as dimly now as was the shape of the electronic age when the Edison effect first was discovered.

The nuclear reactions in a pile chiefly lie in the energy range below 10 million electron volts. Until recently the most energetic laboratory radiation was from the cyclotron, and it did not exceed 40 million electron volts, but now a whole new energy range between 50 million electron volts and 100 million electron volts is being explored with the large betatron at Schenectady and generation of still higher energy particles of the cosmic rays, up to 10^8 million electron volts will uncover even further domains in the nucleus.

The field of nuclear physics offers a vast unknown to explore, an endless frontier. The goal is the vast storehouse of energy in the atom—10 billion kilowatt-hours per pound. Today, by fission, only 1/1,000 of this potential energy has been obtained. To increase that fraction is the task confronting nuclear research.

II. Economics of Atomic Energy

PHILIP W. SWAIN

BLUNTLY STATED, this article attempts to reach economic conclusions regarding atomic power without possessing the essential data. The Smyth report left much unsaid. Since Smyth, no significant new facts have been made public. The vast atomic-energy literature of this "post-Smyth" period is either a restatement of Smyth, a presentation of what was public knowledge before Smyth, an interpretation, or a prediction. For sound reasons of national security, all further information of fundamental character has been kept secret.

Those who write and speak on nuclear energy must be divided into two groups:

1. Those who do not tell because they do not know.
2. Those Manhattan District insiders who do know and therefore cannot tell.

I fall in the first group.

Following are values unknown to me but essential to valid conclusions regarding atomic power economics:

1. Present and estimated future cost of natural uranium.
2. Present and estimated future cost of natural uranium sufficiently purified for use in piles.
3. Present and estimated future cost of uranium 235 in various concentrations (in U-235–U-238 mixtures).
4. Pile efficiency obtainable with various concentrations.
5. The maximum practicable temperature of pile operation.

This article therefore must be presented on an "if" basis. It cannot even be on the level of the schoolbook problem where the data, though imaginary, are *given* at least. Perhaps then the article should be retitled "how to prepare to think economically about atomic power if and when the necessary data become available."

Fortunately the world *does* know the composition of commericial uranium and the energy released by the fission of U-235, so let us begin at that point. Natural uranium contains 0.7 per cent of U-235; 140 pounds of natural uranium contain 1 pound of U-235. The complete fission of the atoms in one pound of U-235 releases in heat energy 11.4 million kilowatt-hours, 39 billion Btu, 30 trillion foot pounds, or the heat in 1,400 tons of good coal.

As 140 pounds of natural uranium contains one pound of U-235, one pound of natural uranium equals ten tons of coal. From this one might reach the false conclusion that coal would have to sell for 20 cents a ton to compete with natural uranium as a fuel.

NATURAL URANIUM PILES

The daily operation of the big carbon-uranium piles at Hanford, Wash., is proof that natural uranium can be used to generate heat at a controlled rate, with the artificial element plutonium as a by-product, even though at Hanford the plutonium (substitute for U-235 in bombs) is the product and the heat an unwanted by-product wasted to the Columbia River at the rate of several hundred thousand kilowatts.

Here are some of the things we are permitted to know about these natural uranium piles, great water-cooled carbon blocks with holes in which are inserted uranium cylinders sealed in aluminum cans. These piles "cook" at a completely controllable rate. They give off heat, and produce plutonium by the action on the U-238 of neutrons produced by U-235 fission. Long before the mass of U-235 in the pile has been consumed the pile slows down, "poisoned" by the accumulation of fission products, so the charge either must be renewed completely or taken out and chemically cleaned up.

To work at all, a natural uranium pile must be very large. With only 0.7 per cent of U-235, natural uranium is a very "weak" atomic fuel. One might view it as the nuclear equivalent of a very high-ash lignite disinclined to burn at all. If the pile is too small it will not maintain a chain reaction. Also, if the natural uranium pile becomes too hot the neutrons are speeded up, make fewer nuclear hits, and the chain reaction dies out unless the pile is made extra large to protect against this.

If the U-235 is enriched—that is, raised above the natural 0.7 per cent by the gaseous diffusion process or other means—a smaller pile can be made to work, and a larger percentage of the available heat of the U-235 can be recovered before the charge must be renewed.

This matter of limiting size may not be particularly important for nonmobile applications of atomic power. The need for heavy shielding and expert operation and close government inspection in any case would limit economic atomic-heat installations to fairly large plants; central electric power plants, central heating plants, and large industrial steam and power plants.

EFFECT OF U-235 CONCENTRATION

Neglecting the size limitation, therefore, it would appear that the optimum percentage of U-235 would be determined by balancing the cost of concentrating against the lower pile efficiency with low concentrations.

Here my estimates suffer greatly from lack of any data, even the roughest approximations. I merely can say that the efficiency of the natural uranium pile is extremely low, that a moderate increase in U-235 gives a substantial improvement in pile efficiency, that the cost of concentrating the U-235 is very high, particularly in the early stages.

To dramatize this last statement, consider 140 pounds of natural uranium containing 1 pound of U-235, or 0.7 per cent. Getting rid of 69.5 pounds of U-238 will raise the U-235 percentage to 1.4 per cent. Getting rid of another 69.5 pounds of U-238 will raise the U-235 percentage to 100.

If and when data become available on the cost of U-235 per pound in various concentrations, and on the corresponding pile efficiency, one can multiply 39 billion Btu by the efficiency to obtain the recovered heat per pound of U-235, and divide this by the cost per pound of U-235 to obtain the Btu recovered per fuel dollar for the given U-235 concentration.

One can guess that the optimum percentage of U-235 will be substantially more than the natural 0.7 per cent, but far less than 100 per cent.

This article can offer no hint as to present pile temperatures, or the limiting temperatures believed to be practicable in pile operation. Official statements suggest that it may be difficult to operate at temperatures high enough for power purposes. It seems quite possible, however, that such statements may be founded on excessive ideas as to what temperatures are required commercially.

PROCESS STEAM MAJOR APPLICATION

Much publicity has been given to steam electric power plants operating at 1,400 pounds per square inch, and at temperatures up to 900 degrees Fahrenheit or higher. Now if atomic energy is to be used to save coal, it makes no difference whether the coal saved makes steam for electric generation or for space heating and process. The combined coal and equivalent coal consumption of all steam electric stations in the United States in 1945 was just under 100 million tons. In the same year medium and large industries burned about 200 million tons in power-type boilers. Most of the steam so produced was applied to heating and process at pressures of 50 pounds per square inch gauge or less. A large part of this steam never went to any prime mover.

Note that 50 pounds per square inch gauge saturated steam, suitable for the majority of process and heating applications, has a temperature of 298 degrees Fahrenheit. Of those plants generating by-product power in turbines exhausting to process, the majority can be taken care of by steam at less than 300 pounds per square inch gauge (422 degree Fahrenheit saturation temperature) and 650 degree Fahrenheit total steam temperature. It must be remembered that back-pressure turbines require a much lower throttle temperature than condensing turbines for a given throttle pressure.

Even if the 650 degrees Fahrenheit should prove to be a pile limitation, the pile presumably could be used to produce the saturated steam at 422 degrees Fahrenheit and then normal fuels used in small quantity to superheat it. Electricity also has been suggested as a means of superheating in such cases, but this obviously is uneconomic.

Among the suggested causes limiting pile temperatures are corrosion or softening of the uranium or the aluminum cans, wastage of the carbon, and thermal stresses in the carbon structure caused by excessively steep temperature gradients. This, in turn, suggests that the temperature limit is not fixed precisely, but rather can be raised considerably if the owner is willing to spend more for the plant and incur more difficulty in operating it.

NO SAVING IN PLANT COST

It is obvious that the replacement of coal by uranium affects only those parts of a power plant devoted to steam generation and the handling of the fuel and ash (or other waste and by-products). While less space would be required for uranium storage, there is little hope that all these elements would cost less either to build or to operate and maintain than those of a conventional steam plant. Heavy radiation shielding and elaborate instrumentation would be needed, also highly skilled operators and inspectors. The disposal of radioactive by-products would be a most difficult matter. Tubes or drums still would be needed to contain the water and steam under pressure.

This all leads up to the conclusion that U-235 will not be used commercially for large-scale steam generation in stationary plants until it can compete with local coal, oil, or gas on a fuel dollar basis, with allowances for the relative steam generating efficiencies (and in some cases for the temperature limitations of the atomic piles).

Table I lists prices at which U-235 would break even with other fuels, "other things being equal." Remember that other things rarely will be equal. On the other hand, note that this does not imply the need to purchase separated U-235. It implies U-235 in the concentration used.

Without further particulars, those "in the know" say that U-235 substantially concentrated costs many times the amounts tabulated. Past industrial history suggests that improved methods eventually will cut the cost to a fraction of present costs. Whether this eventually will bring uranium into actual competition with coal the writer has no way to determine. Take your choice of guesses that range from ten years to centuries.

Table I. U-235 Could Compete at These Prices
*(Other Things Being Equal)**

Common Fuel	Assumed Prices (in Dollars)	Comparable Prices for U-235, Dollars Per Pound (Nearest Thousand)
Coal (13,000 Btu)	6.00 per ton	9,000
	12.00 per ton	18,000
	15.00 per ton	23,000
Fuel oil (150,000 Btu per gallon)	0.02 per gallon	5,000
	0.04 per gallon	10,000
	0.08 per gallon	20,000
City gas (500 Btu)	0.50 per 1,000 cubic feet	39,000
	1.00 per 1,000 cubic feet	78,000
Natural gas (1,000 Btu)	0.25 per 1,000 cubic feet	10,000
	0.50 per 1,000 cubic feet	20,000
	1.00 per 1,000 cubic feet	40,000
Gasoline (150,000 Btu per gallon)	0.10 per gallon	26,000
	0.20 per gallon	52,000
	0.30 per gallon	78,000

* Note that "other things" are never equal. U-235 in normal uranium form is by far the cheapest, but involves use of excessively large and inefficient "piles." The unit cost of the U-235 in enriched mixtures increases with the degree of enrichment. Over-all cost comparisons can be made only for a specified concentration of U-235 and for apparatus suitable for that particular concentration. Possible explosion danger and need to protect personnel against radiation are other important considerations.

NO ECONOMIC REVOLUTION

One thing is certain, however, those who look for an economic revolution resulting from coal-free power are on the wrong track. Coal is a mere fraction of the delivered cost of power. For years we have had technically practicable ways to make power without coal; hydroelectric power, wind power, tide power, sun power. Each of the last three could produce every kilowatt hour used in the United States today and thereby save *all* the coal used in central power stations, but it could not be done economically. Hydroelectric power does little better (and sometimes much worse) than run neck and neck with power from coal-fired steam-electric plants.

If we, nevertheless, should use atom splitting to replace the 100 million tons of utility coal and the 200 million tons of large-industry steam coal, all at $6 per ton, for instance, the saving before allowance for nuclear costs would be little more than one per cent of the national income. This is no revolution, except for coal men.

CONCLUSION

Let me conclude with a few random thoughts for the record.

First, note that cost of natural uranium, even if it be raised from $2 per pound to $10 per pound, is a negligible factor in the cost of atomic fuels. The cost resides mainly in the process of concentrating the U-235, although an appreciable percentage lies in purifying the natural uranium.

Next, I must not seem to rule out the possibility of piles that will make use of plutonium as well as U-235 and other "transuranic" elements, or of other natural elements such as thorium. I also must admit the theoretical possibility that some day we may secure large amounts of energy by synthesizing the light elements into heavier elements, just as the sun makes its heat by turning hydrogen into helium. Although I shall not go into that question I see some promise in the direct atomic heating of helium in a closed circuit gas turbine.

Finally, I should state my sincere belief that power-plant economics is by no means the most pressing problem in the field of nuclear energy. The main problem is that of atomic bombs and rockets. Our first task is to contrive international arrangements which can prevent the mutual destruction of nations by atomic weapons. Meanwhile, let us maintain atomic research as the second responsibility, for "nucleonics" promises developments as strange and wonderful as those that grew from the experiments of Faraday and other electrical pioneers. Nuclear-biological research alone may yield results matching the importance the future power-plant applications of atomic energy.

III. Application to the Generation of Electric Power

J. A. HUTCHESON

IT IS ONLY SINCE THE TURN of the century that the general subject of nuclear physics has been advanced to its present state. Prior to World War II much research and investigation had been carried on in this field with the result that some of the potentialities locked within the atom were becoming apparent to a few individuals. Books had been written which contained enough information to make people in engineering fields generally aware that the application of atomic energy in the field of the generation of electric power might some day be a possibility.

Nevertheless, a competent survey of physics which was published in 1943 contains this statement: "The relatively scarce isotope of uranium of atomic weight 235 is interesting, because it is the one which is usually split. If it were possible to obtain a large quantity of this isotope alone, it would yield in splitting a huge store of energy which might be applied to running engines of war. Dangerous radiations would be emitted, however, in this process, and on all accounts we may be glad that the separation of isotopes is a very difficult and inefficient process." Thus, we see that three years ago there was still very little available knowledge.

When the first atomic bomb was dropped on Hiroshima last August, the situation was altered overnight. It was immediately apparent that here was an application of atomic energy which was of sufficient magnitude to indicate that new knowledge was available in the field of nuclear physics. So far as the engineering profession knew prior to that time, the fission of uranium was accompanied by the release of energy which, though relatively very great, it still required sensitive instru-

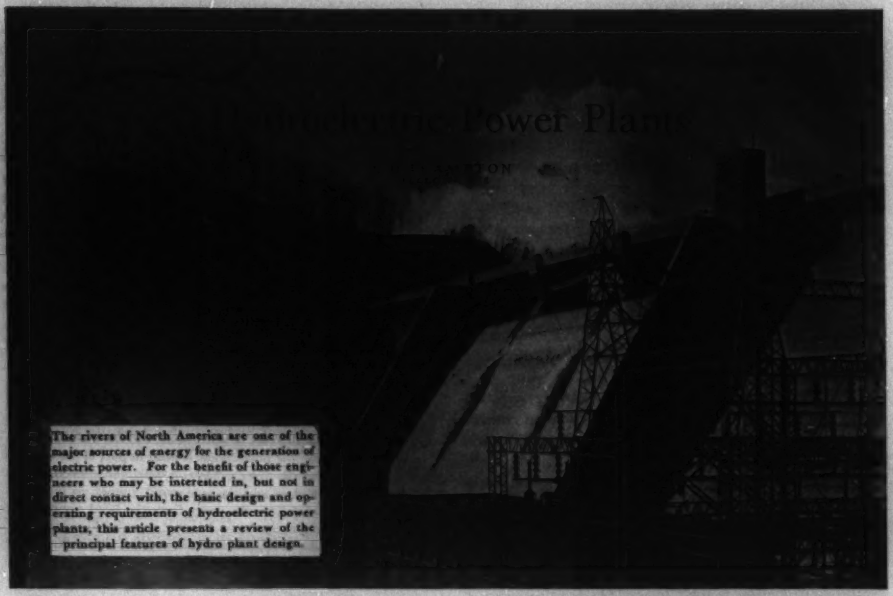
ments to detect. Obviously, during the war years something must have happened which very radically altered this condition. A broad idea of what had happened was forthcoming with the publication of the Smyth Report, and following its publication, many conferences and meetings were held at which the various aspects of atomic energy were discussed with some freedom and with the consequent release of much information. The engineer now has at his command a substantial store of information on which to base a new consideration of the problem of the application of atomic energy to the field of generation of electric power, though not enough information is available to permit the engineer to make an unqualified prediction.

An analysis of the information contained in the Smyth Report and elsewhere brings to light several facts pertinent in this consideration. For example, Doctor A. H. Compton has said, "At present controlled atomic power in the form of heat is in continuous production in large quantities at several plants, especially those at Oak Ridge, Tenn., and at Hanford, Wash. The heat from these plants is a by-product and is carried away in the one case by air and in the other by a stream of water." Not a great deal has been said about the amount of power available in this form at those locations. However, by inference it seems reasonable to suppose that it must be in the order of many thousands of kilowatts. This is borne out by a discussion reported in the Edison Electric Institute *Bulletin* for December 1945, on the subject of atomic energy which included several statements indicating that it was technically possible to develop a power plant of 100,000-kw capacity. The consensus seemed to be that, while it was technically possible, it might not be economic at this time, and further that intensive research and development would be required prior to the attainment of such a plant.

From Doctor Compton's statement it is apparent that the power is available in the form of heat in water, and therefore it seems logical to suspect that the earliest applications of atomic power will be similar to the present scheme of obtaining power from coal, in that steam probably will be used to drive the turbine and that the heat liberated in connection with the fission of some material will be used to form the steam. If this is so, the problems associated with this work will be those brought about by the replacement of the present boiler and coal combustion equipment with some suitable heat exchanger and atomic power equipment.

Many difficulties have to be surmounted before a satisfactory power plant will be achieved. The major one that seems to present tough problems arises from the fact that the whole operation is accompanied by the production of very intense and dangerous radiations. Doctor Compton, in speaking on this subject, has said, "There is, however, a lower limit to the size and weight of an atomic power plant that is imposed by the massive shield needed to prevent the neutrons and other dangerous radiations from getting out. Next to cosmic rays these radiations are the most penetrating that we know, and for a plant designed to deliver, for example, no more than 100 horsepower, are enormously more intense than the rays from a large supply of radium or an X-ray tube. To stop them, a shield equivalent in weight to at least two or three feet of solid steel is needed. There are basic laws of physics that make it appear very unlikely that a lighter shield can be devised. This means that there is no reason to hope that atomic power units for normal uses can be built that will weigh less than perhaps 50 tons." These radiations induce artificial radioactivity in most things they strike, which means that the steam passing through the turbine, for example, probably will be radioactive. The by-products of fission also are radioactive and presumably will need to be removed from time to time. Consequently, special methods of handling and storing them will have to be provided.

With these problems in mind and with certain assumptions about cost of equipment and raw material, it is now possible to make some estimates as to the economic possibilities of the application of atomic energy in the electric power field. A very comprehensive report on this subject has been prepared under the direction of Mr. C. F. Wagner of the Westinghouse Electric Corporation. An assumption is made in the report that an atomic-powered 100,000-kw plant could be built, in which the cost of the equipment and plant necessary to provide steam for the turbines would be about $12,000,000. This is roughly four times the cost of the steam end of an equivalent power plant using coal as a fuel. Calculations were made comparing the cost of power obtained from this atomic power plant with that obtained from a coal power plant. These calculations included amortization of the investment in each case at the rate of 15 per cent per year. It was assumed further that the atomic fuel would be refined natural uranium such as was used in the "piles" at Hanford and Oak Ridge. If it is assumed that this material costs $20 a pound, the total cost of the generation of electric power in the atomic power plant appears to be slightly less than in the coal-fired plant, assuming that coal costs $5 a ton. This comparison would indicate that the possible application of atomic energy to the production of electric power is sufficiently feasible to warrant a careful and thorough investigation. Undoubtedly, work of this kind is going forward; and, consequently, it seems reasonable to predict that within a few years sufficient knowledge will be at hand to permit an accurate analysis to be made which may well indicate that atomic energy as the source of power for an electric power system will be technically feasible and economically practical. From what can be seen now, it appears that the technical problems rather than the economic problems are the ones which must be solved before atomic power plant of the future is practical.



The rivers of North America are one of the major sources of energy for the generation of electric power. For the benefit of those engineers who may be interested in, but not in direct contact with, the basic design and operating requirements of hydroelectric power plants, this article presents a review of the principal features of hydro plant design.

ELECTRIC UTILITY SYSTEMS on the North American continent derive their power supply predominantly from generating stations of either the steam-electric or hydroelectric type. It happens that in some utilities the one type predominates, while in others it may be almost or even completely absent. Consequently, the system engineer and power plant designer may acquire a full familiarity with the problems of location, design, and interconnection with the system of the one type of plant, while being less familiar with the problems associated with the other. It is assumed that the readers of this article are fully familiar with steam-electric plant problems, but would be interested in a general outline of some of the variations encountered in hydroelectric plant design.

In discussing the basic features of design of the hydroelectric plant it may be assumed that it is being added to a system already supplied entirely from similar sources, or that it is being added to a system wherein the major sources of supply are existing steam-electric plants. This article is limited to the former situation.

Hydroelectric plant design differs from the design of metropolitan-type steam stations in several major particulars. The sites for development are fixed by nature and may be near to, or remote from, the major load centers involved. The daily, seasonal, or annual load factor at which such plants may be operated usually is not subject to wide variation. The problems of interconnection with the system may be different, normally requiring long high-voltage transmission lines to load-center receiving stations, with provision for load and voltage control and synchronous condensers. Frequently, more than one site is available, in which case the order of development and the designed characteristics of each plant and of its associated transmission system may be governed by an over-all program embracing all sites.

RIVER FLOW

The design of any component part of an electric utility system must rest upon adequate knowledge of the fundamental factors involved. In the hydroelectric plant, the first consideration is the water supply or stream flow. In both the United States and Canada, for the rivers and streams on which potential water power sites exist, data regarding the stream flow are compiled by governmental agencies and through such agencies are made available to the designing engineers. In most cases, such data have been collected over a period of many years. The longer this period of record the more dependable will be the operating characteristics which

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Essential substance of a paper presented at a meeting of the power group of the AIEE Chicago (Ill.) Section, October 11, 1945, and presented informally in New York, N. Y., at the 1946 AIEE winter convention session on "Hydroelectric Systems" under the sponsorship of the AIEE committee on power generation.

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are incorporated in the design of the hydroelectric plant.

Most rivers, at least in the northern part of the United States and in Canada, have widely varying rates of flow. For example, it is stated that the minimum natural flow of the Tennessee River near its junction with the Mississippi River approximated 4,500 cubic feet per second, whereas its probable unregulated flood was nearly 1,000,000 cubic feet per second. At the Chats Falls site on the Ottawa River, which river forms the boundary between the Canadian provinces of Ontario and Quebec, a variation from 9,000 cubic feet per second to 176,000 cubic feet per second was measured, even though this river is partly regulated. On the converse, the St. Lawrence River presents an unusual example of natural regulation, the flow varying only between the approximate limits of 160,000 and 310,000 cubic feet per second, because of the regulating effect of the Great Lakes.

Economical hydroelectric development, therefore, normally includes some form of river flow or flood control, either at the site of the development or at suitable points elsewhere on the watershed. Examples of control of the river flow at the site of the development are found in the Boulder Dam and Grand Coulee projects; of control at distant points, in the tributary river projects of the Tennessee Valley Authority (Fontana and Apalachia, for example).

BASIC ARRANGEMENT OF HYDRAULIC STRUCTURES

The first steps in the design of a hydroelectric plant are carried out by the hydraulic engineer. From the basic data of the stream flow records, surveys at the proposed site, preliminary contour lines, and other information as to the storage possibilities either at or above the site, the hydraulic engineer begins to prepare alternative arrangements for the dam, the powerhouse, water channels, head pond, and tailrace. In this phase of design the hydroelectric project differs from the steam project in that it is only in the unusual case that the problems presented will parallel those existing in other cases; in other words, each hydroelectric project is a separate problem, with its own separate and distinct solutions. Among the factors to be considered are:

Developed Head. The power output of the hydroelectric plant roughly varies directly with the river flow (cubic feet per second) and with the effective head on the turbines. The effective head which may be developed at any site will be controlled by a number of factors, principal among which will be the economic location and height of the dam and the extent of the area to be flooded above the dam. The hydraulic engineer will study various possible arrangements, with the object of selecting the one arrangement which results in maximum output at minimum unit cost.

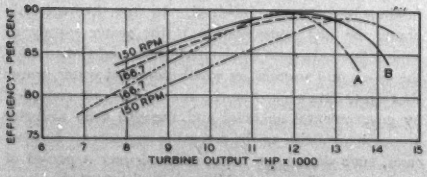


Figure 1. Typical efficiency curves for Francis-type turbines, illustrating possible variations in the shape of the curve

River Flow Conditions. Again because of its effect on plant output, the hydraulic designer will strive for the highest controlled river flow, which means maximum storage capacity. However, it is rarely that the storage possibilities permit the full control of the river flow. Grand Coulee is one such example, but the normal case requires the development of an economic comparison between the cost of establishing storage areas and the revenue to be derived from the increased output resulting from such storage. The Tennessee Valley Authority system contains interesting examples of some tributary developments which provide full control and others (main river developments) in which a major problem has been the provision of spillway capacity to pass extreme flood flows which the development does not control directly.

Means of Introducing Water to the Plant. The topography at the power site provides the hydraulic engineer with a never ending series of problems relating to the arrangement of the dam and the powerhouse and the delivery of water to the turbine water passages. In the simplest case, the powerhouse is built as part of the dam, in the natural bed of the river. More usually the powerhouse is independent of the dam and an open canal, tunnel, or pipe lines will be required to deliver the water from the head pond to the forebay above the powerhouse. In some cases, as for example at the Tennessee Valley Authority Apalachia plant, the intake tunnel is several miles in length. Once again the hydraulic engineer will develop alternative plans, from which a final economic selection may be made.

Means of Conducting Water From the Plant. The static head on the hydroelectric plant will be the net difference in elevation between head water and tail water. The operating head will vary as the head water is drawn down or the tail water raised, under operating conditions. It is obviously equally important to get the water away from the plant efficiently as to deliver it to the plant. The tailrace problem therefore parallels the head water problem, the two being considered jointly.

Total Installed Capacity. The total capacity to be installed at a given site usually is not dictated solely by the hydraulic engineer, as consideration must be given to the problems of generation, transmission, and absorption of the plant output by the system. However, the hydraulic engineer is interested in the limits of load factor for which an economical design can be derived. Generally, where long-distance transmission is involved, a high load-factor is desirable, though, where adequate pondage area (as distinct from long-term storage) can be provided immediately above the plant, operation as a "peaking" plant may be possible, particularly if the cost of the increased capacity is relatively low, including only provision for greater peak water flow and the actual equipment installation.

A special case is the so-called "run-of-river" plant, where storage capacity is virtually nonexistent. The problem then becomes one of deciding what proportion of the flood flow of the river can be developed economically, that is, for what proportion of the hours of the year a unit must operate to justify its installation. Where this type of plant is to be introduced into a system largely steam supplied, a clear-cut economic problem is presented.

As a result of these extensive and generally fairly preliminary studies the hydraulic engineer is able to present for further consideration a series of possible arrangements for any given power site. These will include alternatives as to rated capacity and operating load factor. They also will include variations of arrangement, and provision for such special features as navigation, fishways, flood control, and passage of water for irrigation purposes, as well as provision for electrical and operating requirements, transformer and switchyard locations, and operators' colony.

BASIC STUDY OF SYSTEM REQUIREMENTS

The maximum load concentrations in the average utility system are in the major cities. These cities generally are located such that the cooling water requirements for steam-electric generating stations are found within short distances of the load centers. It follows, though it is recognized that this statement is oversimplified, that the metropolitan steam-electric station can be located to suit load requirements and further that it can be designed for any peak capacity and for any operating load factor consistent with the over-all economy of the system at large. These conditions usually do not apply in hydroelectric developments. Hence, the second steps in the design of additional hydroelectric generating capacity concern the fitting in of available sites to the estimated future demands of the system.

The planning division of the utility will maintain records of daily, seasonal, and annual load demands, both peak and energy. They will record carefully trends in the shape of the daily load curve and of its variations between seasons or between peak and off-peak periods of the year. They will be conversant with the operation of existing plants, the limitations of existing storage reservoirs, and the long-term variations in precipitation on the different watersheds within the system. The records of this division will include projections of load demand into future years, as accurately maintained as economic conditions permit. In general it may be stated that detailed estimates should be available for whatever period in the future would be required to add new capacity to the system, usually a period of the order of two years. Beyond such period future load estimates are indicative of possibilities only, as such estimates seldom can be considered dependable.

Where the system logically may be subdivided into major load areas, these various data similarly will be subdivided, in order that the generating capacity available in and the load demands of each area may be studied independently. In this way the peak and energy transfer requirements between areas, under both normal and possible emergency conditions, may be studied and compared with the capacity of existing interconnecting facilities.

In the system predominantly supplied from hydroelectric resources over long-distance transmission lines,

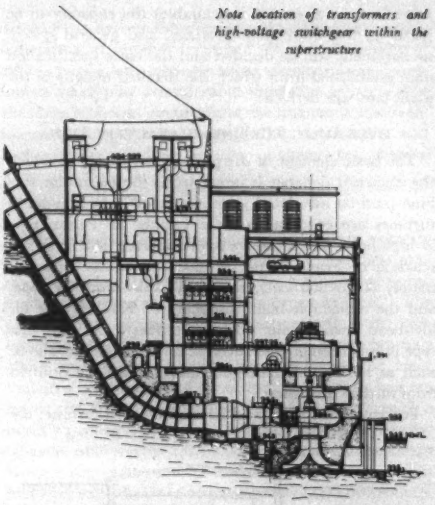


Figure 2. Cross section of the Queenston development of the Hydro-Electric Power Commission of Ontario

a more critical analysis of kilovar distribution usually will be required than in the more compact steam-supplied system. For this reason, the system records maintained will include data as to kilovar distribution paralleling the records of kilowatt capacity and demand.

These various data provide the planning division with the means of conducting system studies, the object of which will be to determine, at any time, specifications for the new generating requirements and the most advantageous point of connection to the existing system. Under certain conditions, the new plant may be required to be capable of operation at high average load factors; under other conditions, peak capacity only may be necessary. Certain arrangements may effect a better control of voltage regulation, having regard to the distribution of the kilovar requirements. System kilovars may be supplied from three sources—unregulated capacitor installations near the load, regulated capacitor banks or synchronous condensers at load centers, or from the kilovar capacity of the generating units. These studies will indicate the answer to the problem of what proportion may be supplied economically from the new generating source, thus establishing the desirable power factor rating of the new generators.

Assuming, therefore, that more than one new site is available for development, system studies, combining technical and economic comparisons, will indicate that site which first should be developed. For this site (or

where only a given site is available) the capacity to be installed, the transmission voltage, and general system arrangement will be decided and the basic specification data established from which the detailed designs of the plant later are derived.

HYDRAULIC TURBINE CHARACTERISTICS

The basic element in the powerhouse design in which the electrical designer is interested is the hydraulic turbine (and its associated water passages). Four types of turbines are encountered—the impulse or Pelton type in high-head plants (above approximately 800 feet), the reaction or Francis type for moderate heads (approximately 60 to 800 feet), the fixed-blade propeller type, and the adjustable-blade propeller or Kaplan type for low-head installations (below 70 feet). As the first type is not common and involves unusual considerations, such as horizontal shaft generators, it will be omitted from further discussion.

For any given plant and for a given type turbine, the

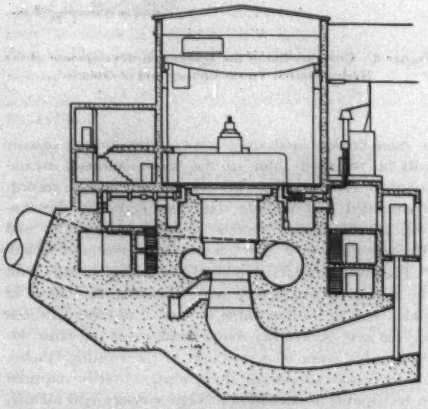


Figure 3. Cross section of a typical moderate-head plant, with transformers located on the tailrace deck

developed head and the total operating capacity fixes, within rather narrow limits, the number and capacity of the generating units and also the speed of rotation. At a given speed, increasing the capacity (or, for a given capacity, increasing the speed) beyond certain well defined limits introduces the problem of runner cavitation. Here will be noted a basic difference from steam-electric plant design, where the selection of the capacity and speed is wholly in the designer's hands. When the head and capacity conditions permit a choice, approximately 50 per cent higher operating speed is obtained using the propeller type unit as against the Francis type, though the overspeed for which the generator must be designed may be nearly 300 per cent in the case of Kaplan units, as compared to approximately 200 per cent for fixed-blade propeller and 180 per cent for Francis type turbines operating at normal rated head.

The electrical designer has a particular interest in the fact that hydraulic considerations control the turbine speed. The speed obviously governs the generator design and may control the spacing of units, determine the superstructure design, crane capacity, and erection bay space requirements. It is of interest to note that European practice tends toward higher speeds than are used on the North American continent. European designs permit of higher water velocities entering and leaving the turbine, velocities which hydraulic designers in North America currently consider reach into the field where cavitation becomes a major consideration. However, the continental designer may make an extensive use of stainless steel, particularly in the runner blades of propeller type units, to permit increasing the allowable cavitation factor. American designers and utility engineers are facing an interesting problem in this regard, in balancing the saving in capital cost resulting from higher speeds against the increased costs of maintenance of runners which suffer from cavitation.

The system engineer will be interested also in the plant efficiency curve. In the hydroelectric plant, the efficiency of the hydraulic design (water passages and turbine) cannot be predicted with the accuracy of, say, an electric generator design. Quite usually the draft tube design is dictated by the turbine manufacturer and at least one utility permits the manufacturer also to dictate the design of the intake passages. Model tests frequently are resorted to, to compare the efficiency of alternative arrangements or to determine what guarantees are to be submitted in a given case. Depending on the particular arrangements and characteristics selected, the turbine efficiency curve may be peaked sharply as in curve *A* of Figure 1 or have a relatively flat section at and near maximum efficiency as in curve *B*.

If it is possible to vary the number of units operating as the total plant load varies, so that all units may be operated at maximum efficiency, a peaked efficiency curve may be acceptable. However, if the plant is to provide system regulating capacity, or if for any other reason the units may be required to operate over an extensive load range, a flatter efficiency characteristic may be desirable, even though the actual maximum efficiency be somewhat less. If the head on the plant varies over wide limits, as for example in the main river plants of the Tennessee Valley Authority, this fact may dictate the efficiency characteristics selected.

Hydraulic considerations will control one further feature of interest, namely, the flywheel effect of the generators. The turbine scroll case, penstocks, and other water passages must be designed to withstand the transient pressure rise occasioned by the rejection of load

and the subsequent rapid closing of the turbine gates. It is usual to require that this pressure rise (or the resultant overspeed of the unit) shall not exceed a specified figure, assuming gate closure in from three to six seconds, depending on the head. Unless there are special stability requirements, this specification will govern the flywheel effect which must be incorporated in the generator rotor design.

The type, rating, and speed of the turbine fixes the dimensions of the turbine water passages, which dimensions frequently govern the unit spacing in the powerhouse. The same factors control the elevation of the horizontal center line of the turbines and hence the general dimensions of the powerhouse substructure. Figures 2, 3, and 4 are cross-section drawings of three plants, illustrating some of the variations which may be introduced into the general plant arrangement by hydraulic and other considerations.

Figure 2 is a moderate head plant (approximately 300 feet), in which the turbines are Francis type. Topography at the site and other economic factors dictated the installation of the step-up transformation and high-voltage switching within the powerhouse superstructure, a practice not common today. Figure 3 illustrates the more usual arrangement, also in a moderate head plant with Francis turbines, where the transformation is installed outdoors on a deck above the tailrace. A long horizontal section in the turbine draft tube promotes the use of this arrangement. In other cases, the transformation may be on the upstream side of the superstructure.

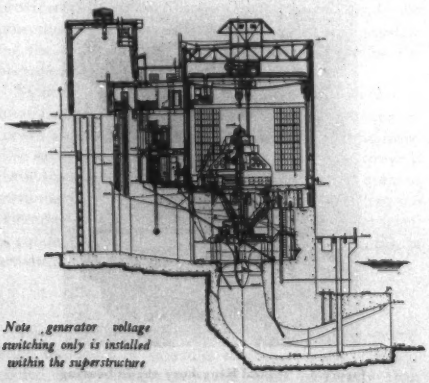


Figure 4. Cross section of the Chats Falls development of the Hydro-Electric Power Commission of Ontario

Figure 4 illustrates a typical low-head plant, in which the turbines are fixed-blade propeller type. In this plant, the generator voltage switching only is installed in the powerhouse, the generator cables being taken some distance to a step-up transformer and high-voltage switching station at another location. In a development of major proportions, the electrical designer is often required to display considerable ingenuity in arranging the main electrical circuits from the frequently relatively inaccessible generators through the transformers and high-voltage switching to the outgoing transmission lines.

GENERATORS

Hydroelectric generating units may range in capacity from 1,000 to approximately 100,000 kw. Speeds may range from less than 100 rpm to an approximate upper limit of 300 rpm (excluding Pelton type turbines). The vertical shaft arrangement is encountered most commonly, having the main thrust and upper guide bearings above and a second guide bearing below the rotor though a combination of thrust and single guide bearing below the rotor (the so-called "umbrella-type" unit) is rapidly gaining in favor. A typical 41,250-kva 109-rpm 60-cycle unit weighs 1,075,000 pounds total, the thrust bearing supporting a combined rotor and runner weight and hydraulic thrust of approximately 1,000,000 pounds. In some larger units, the thrust bearing loading exceeds 3,500,000 pounds.

Insulation. Hydroelectric generators are usually class *B* insulated throughout, for which class of insulation the AIEE Standards permit a temperature rise of 80 degrees centigrade above an ambient temperature of 40 degrees centigrade. However, it is not common to find utilities operating units at this temperature, it being more usual to specify that a generator shall be capable of full output at normal operating voltage with only 60 degrees centigrade rise.

Excitation. Generator voltages, in the larger units, are usually in the 12 kv to 15 kv range, the higher voltages occasionally found in steam-electric units not having been adopted, at least on the North American continent. Excitation, in all but the lowest speed units, is supplied from direct-connected exciters and pilot exciters. Stability being so often a factor in hydroelectric plant operation, the excitation system normally is designed for high-speed operation—the rate of exciter response is of the order of 225 volts per second. The condenser (overexcited) capacity of the typical unit would approximate 60 per cent and the line charging (underexcited) capacity 80 per cent of the normal kilovolt-ampere rating.

Power Factor. The power factor rating of hydroelectric generators is frequently 80 per cent lagging. However, the economic distribution of system kilovars often indicates that such a low rating is uneconomical; in fact, in cases involving high-voltage long-distance transmission lines, even a unity power factor rating may be justified. Here the naturally conservative designer is faced with a compromise between the desire to provide flexibility in the form of excess kilovolt-ampere capacity and the

possible lowering of system stability resulting from units operating underexcited. It is not uncommon to find units rated at 85 per cent to 90 per cent power factor and 95-per-cent-power-factor units were proposed in at least one development with which the author is familiar.

Rating. The relationship between the turbine and the generator rating in hydroelectric plants differs from standard steam practice. It is usual to provide a steam turbine whose kilowatt capacity is equal to the kilovolt-ampere capacity of the usually 80-per-cent-power-factor generator. Hydroelectric units are almost invariably "tailor-made," capacities and speeds seldom corresponding. The degree of standardization proposed for steam-electric generators therefore will be difficult to attain in hydroelectric practice. Furthermore, once the hydraulic design is established, the maximum turbine output varies only with the operating head. The generator kilowatt rating therefore is selected to equal the turbine capacity at some selected or normal head. At such times as the available operating head exceeds this rated figure, the increased turbine output may be provided for, either by operating at higher power factors or by operating at temperatures above the specified 60-degree rise but within the limits permitted by the class *B* insulation.

Reactances. The reactances of hydroelectric generators frequently are controlled by system stability conditions. However, low reactances mean larger machines physically and hence greater cost. The designer faces an interesting problem in balancing the desired characteristics against capital expenditure. Typical direct axis subtransient reactance would approximate 35 per cent and quadrature axis subtransient reactance 75 per cent. Short-circuit ratio normally would lie between 1 and 1.25, though in certain installations a much higher ratio has been specified.

The direct and quadrature axis reactances quoted here assume that pole face or damper windings are not present. Investigations of the past few years indicate that many previously unexplained flashovers, in systems involving long-distance transmission, result from the clearing of a single-phase-to-ground fault only at the distant end of a line, leaving the generation supplying the open-ended and still faulty line under conditions approaching resonance. Material improvement in such conditions is effected by the installation of damper windings, whereby the ratio of quadrature to direct axis subtransient reactances is reduced to less than 1.3. Such windings should be continuous to be most effective, but satisfactory designs have been devised in which the winding is noncontinuous, that is, there are no troublesome bridging sections between the poles.

Thrust Bearings. Two types of thrust bearings are offered by American generator manufacturers—the Kingsbury and spring-supported bearings. The thrust block and runner plate construction is similar in the two, the essential variation being in the stationary bearing surfaces.

In the Kingsbury bearing (Figure 5), the stationary bearing surface is subdivided into several segments, each of which is supported, and subject to individual adjustment, by means of a single vertical spherically headed jackscrew. Adjustment of the bearing and alignment of its surface may be carried out at the bearing itself.

In the spring-supported bearing (Figure 6), the stationary plate is essentially one piece, being split only for assembly around the shaft. This plate is supported on a nest of helical springs, arranged in a tray which is subdivided segmentally. These springs are precompressed and each is machined after compression to within a close tolerance of uniform length. The bearing surface being essentially of one piece, adjustment and alignment of this type of bearing must be effected by the adjustment of the whole bearing bracket.

Figure 5. Typical Kingsbury thrust bearing

The successful operation of bearings of either type, carrying loads up to nearly four million pounds, depends on the degree of finish of the bearing surfaces, the accurate alignment of the generator and turbine shafts and the adjustment of the bearing during erection, and the maintenance of this alignment and adjustment during operation. The critical time in bearing operation is during the first few revolutions of the unit when starting up or the last few revolutions when shutting down, when the danger of there being an incomplete oil film is greatest.

Cooling. All older hydrogenerators were of open construction, self-cooled by the fanning action of the rotor, the oldest units taking air from and discharging air into the powerhouse. Later designs provided duct

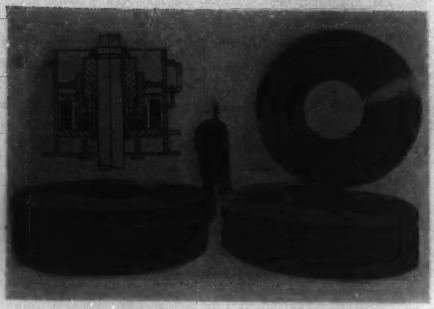


Figure 6. Typical spring-supported thrust bearing

systems, in some of which air could be taken from outside the powerhouse and discharged into the powerhouse and in some of which the reverse arrangement was provided. Again later, more complete duct systems provided both an air intake and discharge outside the powerhouse. Damper arrangements were then possible for the control of generator temperature and for the operation of carbon-dioxide protection.

Modern designs follow turbogenerator practice in totally enclosing the generator stator, cooling being by means of surface coolers incorporated within this housing. The saving in cleaning costs usually will go far towards justifying the increased cost of this design, but its greatest advantage accrues from the possibility of controlling the operating temperatures to a more nearly uniform level, a condition highly effective in prolonging the life of armature insulation.

TRANSFORMERS

The step-up transformation in hydroelectric generating stations is of generally standard design. Water-cooled units perhaps are used more frequently than elsewhere, because of the availability of cooling water, sometimes taken directly from the penstocks under natural head. A variation, which has found less favor than it appears to deserve, is forced-oil cooling with the cooling equipment suspended in the tail water. With a positive oil pressure, leaks need not be feared and the maintenance problems incidental to screening the water supply or cleaning out the cooling system substantially would be avoided.

Three-winding transformers, having two low-voltage windings of one-half capacity and a single high-voltage winding of full capacity, have been adopted in a number of stations, particularly where the higher transmission voltages are employed. Pairs of generating units are connected to each transformer bank. This arrangement stems from the fact previously mentioned, that the unit capacity is determined by hydraulic considerations, whereas the capacity of the transformer bank is limited only by manufacturing and transportation requirements. Such an arrangement effects a definite saving in transformer cost and also a further indirect saving in the high-voltage switching.

MAIN ELECTRICAL CONNECTIONS

As a general statement, it probably may be said that the main electrical connections in the hydroelectric generating station are more simple than in the steam-electric station or main transformer center. The primary problem is to establish as simple an arrangement of switching as will permit the delivery of the output of the generating units to the transmission lines, with the required degree of flexibility in meeting the anticipated normal and emergency operating conditions. This problem will vary in complexity depending upon whether the output of the station is to be delivered to a single load center or whether several groups of units must be connected flexibly in a number of subsystems. In special cases, as for example in stations of the magnitude of Grand Coulee or the proposed St. Lawrence development, the selection of the main electrical diagram may have an important bearing on the system stability conditions.

Personal preferences combine with the operating requirements and economic factors in influencing the final choice of diagram. Some designers prefer the simplicity and low cost of the ring arrangement; others prefer the double bus layout with its greater flexibility at greater cost. With high transmission voltages, an appreciable saving may be effected by the elimination of high-voltage switching, though high voltages usually are associated with greater capacities, so that even generator voltage switching may become a difficult and costly alternative. Nevertheless, there appear to be two distinct trends, one towards concentration on high-voltage switching only and the other toward a similar concentration on low-voltage switching only.

Figure 7 illustrates four types of station diagram using high-voltage switching only. Diagram (a) is the familiar ring diagram, which most system designers would adopt only if the number of breakers required is relatively small. Diagram (b) is a form of diagram adopted as standard by the Tennessee Valley Authority. This diagram has certain disadvantages from the flexibility standpoint and also may introduce complications in the control and protective system.

These disadvantages may be eliminated progressively by an increased number of breakers and corresponding greater cost. Diagram (c) is a so-called "breaker and a half" scheme, which can satisfy rather exacting requirements of system operation, while diagram (d) is the ultimate double-breaker arrangement.

Two diagrams illustrating the elimination of high-voltage switching are shown in Figure 8. Diagram (a) utilizes a ring bus at generator voltage, with the trans-

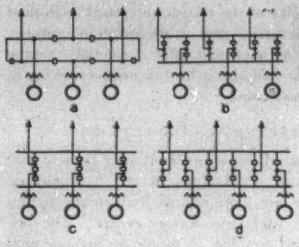


Figure 7. Main station diagrams using only high-voltage switching

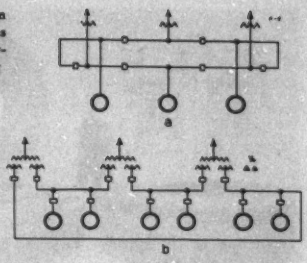


Figure 8. Main station diagrams using only low-voltage switching

former banks directly in the high-voltage lines. Diagram (b) is a form of diagram proposed for at least two major developments on the North American continent.[1] Both these diagrams, it will be noted, involve the loss of a transformer bank coincidental with a line outage. If the output of the plant is not to be reduced and the system is to remain stable under such conditions (as normally would be required), excess capacity must be provided in all transformer banks, the total of which must equal the capacity which would be lost under an emergency condition. Such excess capacity might be provided by normally operating with rated water circulation or without blowers, increasing the circulating water, or placing the blowers automatically into service during line outages.

Low-Voltage Switching. Switching equipment for generator voltages currently is almost invariably of metalclad construction. While many installations are of oil circuit breakers, air-blast equipment is gaining in favor and it would appear that the indoor installation of such equipment, in metalclad structures, provides an excellent solution to the electrical designer's problems.

High-Voltage Switching. Equipment of standard design meets all the requirements of the hydroelectric plant. Circuit breaker speeds would be a function of the system conditions, normal or ultrafast operation being dictated by stability requirements. Automatic reclosure may be applied and single-phase operation may be quite effective, as in many other points in the utility system.

CONTROL

The arrangement of the control, metering, and protective relay equipment in hydroelectric plants is not materially different from that in the modern steam station. The control room is most frequently in a location remote from the main generator floor and will be soundproof, air-conditioned, and indirectly lighted in plants of recent design.

A number of small (and some moderate) capacity plants have been arranged for fully automatic operation—going into service or shutting down without manual attendance, either by push-button control from a supervisory center or under pre-established conditions of system load, frequency, or head water level. Automatic synchronizing, of even the largest units, is becoming standard practice in most utilities.

Automatic load and frequency control is applied in hydroelectric plants as an accepted adjunct to present-day standards of system operation. Where the head water level is required to be held within definite limits, water level control may be combined with the other automatic features.

One feature of control peculiar to hydroelectric development is that of depressing the water in the turbine draft tube to permit operation of the generating unit either as a synchronous condenser or as a unit in spinning reserve. Operation of a unit at part load, in order to utilize the remaining kilovolt-ampere capacity for power factor control, results in inefficient water utilization. If the turbine is set above operating tail water level, closing the turbine gates and breaking the vacuum in the draft tube permits the operation of the unit free of the water drag. When the unit is set below tail water level, compressed air connections may be provided to force the tail water below the runner blades and to maintain this condition during synchronous condenser operation.

This feature has been applied extensively in the plants of the Tennessee Valley Authority where the system conditions are such as to make it of particular value. At certain seasons, while water is being stored, the power output of the eastern (up-river) plants is low and heavy west-to-east transmission line loadings occur. Units in the easterly plants then may be used, with depressed tail water, for voltage control. During dry periods, when storage water is being released, the reverse condition applies and the westerly (down-river) plants may supply the required kilovar capacity. Control is such that units operating as synchronous condensers will return automatically to generator operation in the event of a slight drop in system frequency.

STATION SERVICE AND AUXILIARIES

The station service connections and auxiliary systems in the average hydroelectric plant are much more simple than in its steam counterpart, due to the absence of coal handling, circulating water, boiler plant auxiliaries, and

draft fans. The major service requirements include head gate control, governor pumps, transformer and generator cooling water, lubricating oil and compressed air systems, and cranes and unwatering pumps, together with the usual lighting, heating, ventilating and sanitary requirements, and machine shop and maintenance facilities.

Continuity of service power supply, however, is of

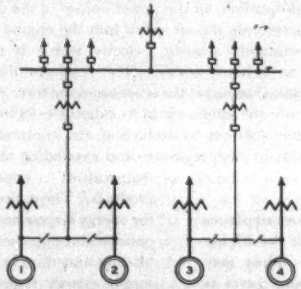


Figure 9. Schematic diagram for station service power connections in a multiunit plant

equal importance. Usually two sources of service power are arranged—in a multiunit plant taken from the generator-transformer leads as is illustrated in Figure 9. A third source may be from an outside system connection. This latter source may be of only nominal capacity, to provide for those services essential to returning the plant to service after a complete shutdown. As a variation, where generator voltage switching is absent, the main service connections may be through transformers stepping down from the high-voltage bus.

Governing requirements in the hydroelectric plant differ from those in the steam-electric station because of the inertia of the moving mass of water. Governor heads in older plants are driven mechanically from the main shaft of the unit—in later plants, electrical drive is more common, either from potential transformers connected to the generator leads or by means of a permanent-magnet generator attached to the main shaft. In some plants, a separate system is provided for the governor fluid; in others, the same oil is used for governor operation as for bearing lubrication. An interesting development in governor practice is seen in the Apalachia plant of the Tennessee Valley Authority, where the governor cabinets are installed in the control room, thus combining all control in the one location, which also, incidentally, is on the main generator floor level.

Circulating cooling water will be limited to that required for the turbine and generator bearings, for the water-cooled transformers, if present, and for generator cooling, where totally enclosed water-cooled generators are used.

The compressed air system will supply service air, the generator brakes, and the tailwater depressing system where used. All hydroelectric generators are equipped with air brakes, the application of which usually is controlled by the governor during both normal and emergency shutdowns. Most designers prefer that the air system for the generator brakes be independent of the station service air, so as to insure its availability at all times.

It is impossible to present details of design within the space limitations of this article. These matters, however, have been treated extensively in AIEE papers and in other technical literature.

REFERENCE

1. Three-Winding Transformer Ring-Bus Characteristics, G. W. Bills, C. A. MacArthur. AIEE *Transactions*, volume 61, 1942, December section, pages 848–9.

Electrical Essays

THIS electrical essay is presented for the recreation of the reader. Can you find the error in the following reasoning?

A capacitance C charged to a voltage E suddenly is connected in parallel with another equal capacitance which is initially unchanged. If negligible inductance in the circuit is assumed, the pair of capacitors should assume almost instantly a potential difference of $E/2$ since the initial charge now will be divided equally between the two capacitors.

If the resistance also is assumed to be negligibly small, this change should take place with no appreciable loss of energy. However, the initial stored energy was $1/2CE^2$, and the final combined stored energy of the two capacitors is

$$2\left[\frac{1}{2}C\left(\frac{E}{2}\right)^2\right]$$

or

$$\frac{1}{4}CE^2$$

Can it be that the law of conservation of energy fails to hold in this case? What is wrong?

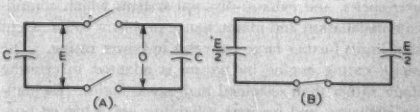


Figure 1

A. $\frac{1}{2}CE^2+0=\frac{1}{2}CE^2$ B. $\frac{1}{2}C\left(\frac{E}{2}\right)^2+\frac{1}{2}C\left(\frac{E}{2}\right)^2=\frac{1}{4}CE^2$

Power Plants for Airplanes

AVIATION PROGRESS throughout its history has been paced by the development of airplane engines. The constant trend has been toward bigger and faster airplanes, consequently toward more powerful engines. Until recently, airplanes were driven only by reciprocating internal-combustion engines. Now there are new power plants and of them, two likely will figure in aviation of the near future. One of them is the jet propulsion engine; the other is the gas turbine–propeller drive. Both will have continuous combustion gas turbines as the prime mover.

While the reciprocating engine undoubtedly will continue to hold its present position in the field of low power and for planes of low speed, the gas turbine will come into its own both as a jet engine, and for driving propellers in high-powered planes and for high-speed flight.

Gas turbines as power plants for airplanes now are providing competition for the highly developed reciprocating engine. They may utilize only the thrust of the exhaust gases as a jet engine, drive a conventional propeller, or combine the two actions. Comparison of the three reveals their relative advantages and fields of application.

Of the three types of power plants, the gas turbine–propeller engine has characteristics that give it superiority over the reciprocating engine in all speed ranges and over the jet engine in low and intermediate speeds. The jet is pre-eminent in the highest speed range. Figure 1 shows the probable fields of use of the three types. These conclusions are reached by comparing the performances of airplanes in which each of the three types of engines might be installed.

THE RECIPROCATING ENGINE

The primary objectives of efficiency, light weight, and reliability have been met by the reciprocating engine. However, power ratings have reached a point where further major increases probably can be attained only by improvements in fuels or the addition of cylinders. The diameter or frontal area of engines already is limited by allowable piston speeds, larger engines are longer engines, and the specific weight is more likely to increase with power rating than decrease. Engines capable of delivering several thousand horsepower require controls, accessories, and exhaust-disposal systems which complicate installation and maintenance problems to an extent that limits further large increases in power rating. The reciprocating engine by nature is adapted to cruising flight rather than sustained high-speed flight. Its highest efficiency and greatest reliability are achieved only when the engine is operated below 60 per cent of rated power. An underpowered airplane is plagued constantly by power-plant troubles of a mechanical nature.

THE GAS TURBINE–JET ENGINE

In jet propulsion, all the power output of the engine is used to accelerate the air taken into the engine to a jet of approximately acoustic velocity which is expelled through an exhaust nozzle. The resultant thrust felt by the engine housing is the reaction to the force required to accelerate the intake air to its exhaust velocity. The gas turbine operates by inducting air, compressing it, adding heat at high pressure, and expanding the high-temperature combustion products. The major part of the energy is recovered in expansion through the turbine blading and must be used to supply energy required for compression. The remainder of the expansion can be made to take place through a nozzle, where the energy appears as kinetic energy of the exhaust gases.

Principal advantages of the jet engine are its simplicity and light weight. The installed weight of the jet-propulsion engine is little higher than its dry weight, since little oil is required for lubrication, and the engine itself requires no external cooling provisions. The jet engine's

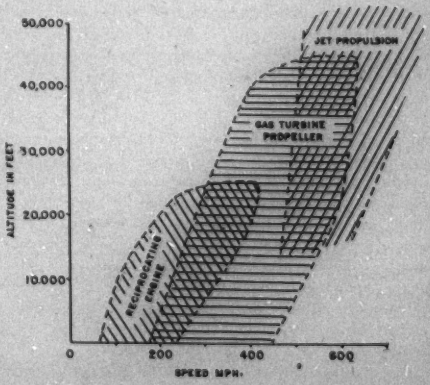


Figure 1. Probable fields of use of the three types of aircraft power plants of the near future

Extracted from "The Place of the Gas Turbine in Aviation" by Charles D. Flagle, design engineer in the aviation gas turbine division of the Westinghouse Electric Corporation, South Philadelphia, Pa., and Frank W. Godsey, Jr. (M '36) manager of the new products division of the same company at East Pittsburgh, Pa.

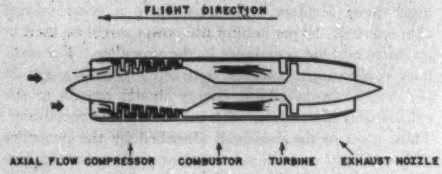


Figure 2. Schematic illustration of an aircraft jet propulsion engine with axial flow compressor and in-line combustor and turbine

thrust is relatively constant over normal airplane speed ranges. Therefore, the rating of a jet engine usually is given in terms of thrust rather than horsepower and means nothing from a power standpoint until the speed also is given. A thrust of one pound at a speed of 375 miles per hour is equivalent to one horsepower; at lower speeds the power rating decreases and at higher speeds it increases in direct proportion.

An adjustable-pitch propeller is capable of converting shaft power into thrust horsepower rather efficiently over a wide range of airplane speeds, but the jet engine's efficiency is quite low at low speeds. Below 500 miles per hour the jet efficiency, and consequently its fuel economy, are inferior. The fuel efficiency of a jet engine is low because of the jet efficiency characteristic and because the gas turbine itself operating at a low-compression ratio is handicapped in efficiency.

It is significant to note that jet efficiency overtakes propeller efficiency in a speed range in which compressibility effects impose critical aircraft-design limitations. Much aerodynamic research must be carried out before jet propulsion can be utilized to its best advantage.

THE GAS TURBINE–PROPELLER DRIVE

A simple open-cycle gas turbine can be built today to work at a peak temperature (temperature of gases entering the turbine) of 1,500 degrees Fahrenheit. With further metallurgical progress, the life of highly stressed turbine parts operating under high temperature will be increased and the limiting-cycle temperature may be elevated above 1,500 degrees. With a compression ratio of ten to one and compressor and turbine efficiencies of 85 per cent, a fuel efficiency of 26 per cent can be achieved. By increasing compressor efficiency to 87 per cent and turbine efficiency to 89 per cent a rise in efficiency to 28 per cent at standard sea level conditions can be expected. At 15,000 feet, due to low ambient temperatures, the cycle efficiency rises to 31.5 per cent.

The efficiency of a gas turbine is highest at its rated load and rated speed. As speed decreases, the efficiencies of compression and expansion drop off and the compression ratio also decreases rapidly. Since the useful power output of the machine is the relatively small difference between the power developed by the turbine and power absorbed by the compressor, any change in compressor or turbine efficiency is magnified in its effect on power output.

The gas turbine for propeller drive operates on four to eight times the quantity of air used by a reciprocating engine of comparable power. A large exhaust jet thrust is available to supplement the propeller, since normally about 20 per cent of the useful power remains in the exhaust gases as kinetic energy; the proportion of useful power remaining in the exhaust to power delivered to the propeller can be controlled by the designer. In general, operations at normal flight altitudes are favorable to economical turbine performance. For rough approximation, the exhaust jet thrust just about compensates for propeller losses and nacelle and cooling drag, so that the shaft power output of the turbine is just about equal to the net thrust horsepower available. This is very different from the reciprocating engine.

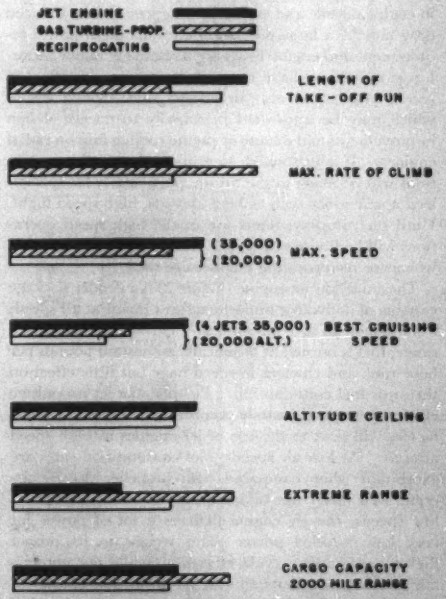


Figure 3. General comparisons of the characteristics of three types of airplane power plants

The gas turbine is not a supercharged engine. Therefore, the selection of power rating must be based on altitude requirements; and for sea level operation, considerable excess power usually will be available.

THE AIRPLANE AND THE POWER PLANT

The reciprocating engine, in its normal cruising power range, is a very efficient means of converting fuel energy into shaft power. However, its application to aircraft is complicated by many difficult problems, among which are the necessity for supercharging at high altitudes, severe vibration, excessive weight installed as compared with dry engine weight, and high nacelle drag and engine cooling power losses. For medium range and long range aircraft, the most important problems are probably the reduction of nacelle drag and engine cooling losses. Airplanes designed for low speed operations can afford to have a large part of the airplane's parasitic drag absorbed in engine nacelle and engine cooling losses, since induced drag may be a large portion of the total flight power requirement and engine losses are a relatively minor factor. Large reductions have been made in propeller losses in recent years, and also in nacelle and cooling drags, which may be attributed principally to nacelle design improvements and the use of engine cooling fans on radial engines. It is reasonable to suppose that further reductions will be made in the future, particularly for specialized applications such as high altitude, high speed flight. Until such improvements are made, high speed operations will be limited by power plant rather than airframe whenever reciprocating engines are used.

The axial flow jet engine (Figure 2) is a slender package capable of delivering almost constant thrust at all speeds from takeoff to dive maximum. Throughout this speed range, fuel is burned at practically a constant pounds per hour rate, and changes in speed have but little effect on thrust or fuel consumption. Further, the jet propulsive efficiency is approximately proportional to speed. These factors will lead to the use of jet engines in high speed aircraft. At low air speeds, fuel consumption rates are exorbitant when compared with propeller driven aircraft. To offset the disadvantage of low efficiency at low speeds, the jet engine delivers a lot of power for very low installed power plant weight in its proper flight speed range; cycle efficiency, while not good, is fair which means low fuel cost per thrust horsepower at very high speeds, and the engine's diameter is small enough to permit buried installations in the wings of any but the smallest planes.

The gas turbine geared to a propeller has the advantages of the jet engine with respect to drag reduction and ease of installation, while at the same time retaining the high propulsive efficiency of the propeller at low speeds. The present limit of usefulness of the geared propeller turbine at high flight speeds is set by the characteristics of available propellers which lose quite rapidly in efficiency above 500 miles per hour. The principal and immediate advantage of the geared propeller gas turbine is a large reduction in airplane drag.

It is possible to make a choice of the division of power outputs of a turbine propeller unit between jet exhaust thrust and the propeller shaft. For example, for a very high speed airplane that must have a good takeoff characteristic, 50 per cent of the power might be used in jet thrust and the remainder in the propeller. For ordinary applications, however, between 20 per cent and 25 per cent of the available energy should remain in the exhaust jet, the turbine shaft recovering the remainder. Thus, most of the energy is absorbed by the propeller with excellent over-all power plant performance at low flight speeds, and with fuel economy at high power levels that is quite superior to the conventional power plant. The field of usefulness of the gas turbine with propeller then extends to all aircraft requiring engines of greater than perhaps 1,000–2,000 horsepower and designed for all speeds up to and in excess of 500 miles per hour.

The general characteristics of the three airplanes are compared by the bar charts of Figure 3. The gas turbine–propeller airplane is superior to the conventional aircraft on every count with the exception of altitude ceiling, where they are about equal if the reciprocating engines are turbosupercharged. Because turbine propeller fuel economy and installed power plant weights are both superior to those of the conventional engine, the long range and short range load carrying abilities of the turbine propeller aircraft are superior to the conventional one. The jet propelled aircraft has a very light power plant installation and can get off the ground for very short flights with about five tons more payload than the conventional aircraft, and about three tons more than the turbine propeller version, but requires so much more fuel than other types that at about 2,000 miles extreme range the jet plane loses out to the reciprocating engine and is far behind the geared turbine in payload carrying ability.

Figure 4 (right). Flight and propulsion spectrum

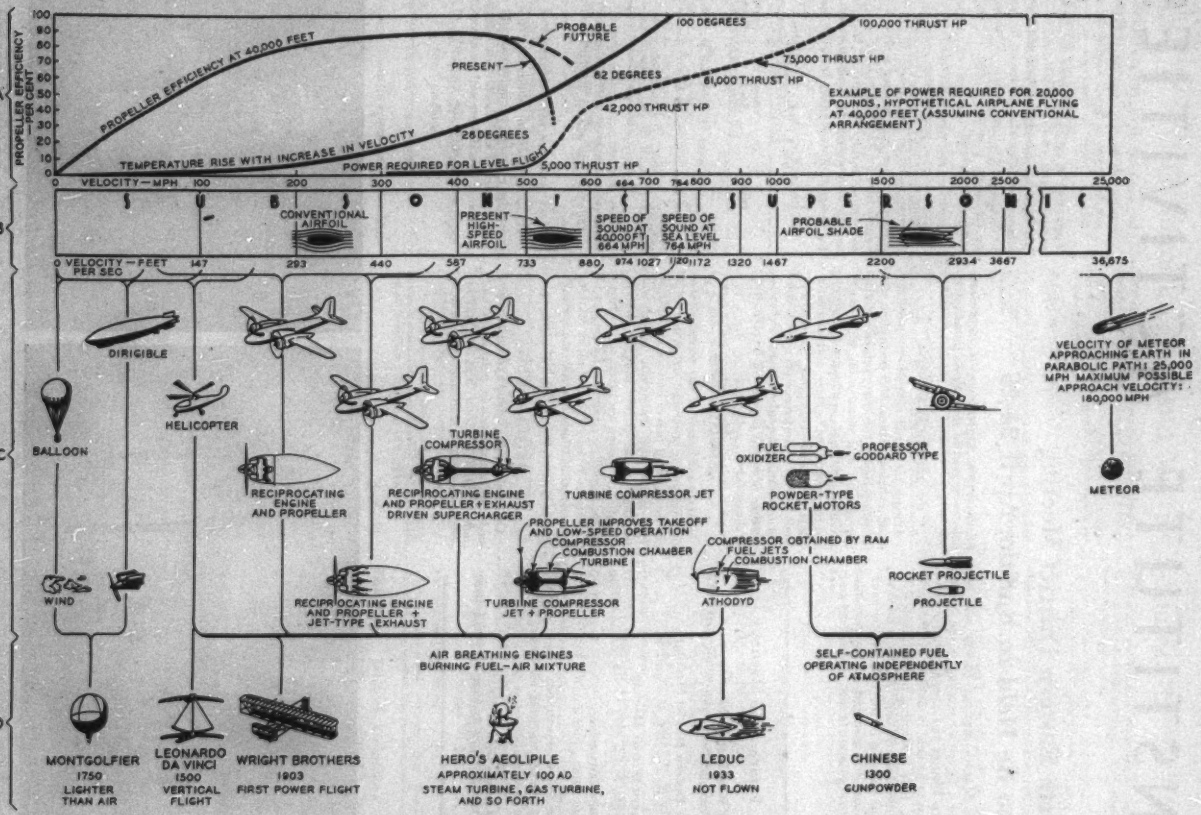
In section *A* curve of propeller efficiency shows limitations of propeller driven aircraft, which approximate 500 miles per hour, and leads to the conclusion that jet propulsion will be required for greater speeds. Second curve illustrates how temperature of a body traveling in earth's atmosphere increases with velocity and shows necessity either of employing a system of cooling or operating at higher altitudes where effective heat rise is less. Third curve illustrates presently insurmountable problem of attaining velocities of 600 miles per hour or greater with a propeller driven conventional 20,000-pound airplane flying at 40,000 feet

Section *B* illustrates probable evolution of high speed airfoils. That on right of spectrum, although suitable for these speeds, presents the problem of obtaining low speeds for landing

Section *C* shows evolution of flight in earth's atmosphere, from the slowest, the free balloon, to the fastest, the meteor. Between these two, flight can be placed in three groups:

1. Lighter-than-air ships
2. Heavier-than-air craft powered by air-breathing engines with propellers or by air-breathing jet engines with no propellers
3. Non-air-breathing rockets, projectiles

In section *D* is shown the simple origin of many present and future principles of aviation


PROPELLER EFFICIENCY—PER CENT
PROPELLER EFFICIENCY AT 40,000 FEET
PROBABLE FUTURE
PRESENT
100 DEGREES
82 DEGREES
28 DEGREES
TEMPERATURE RISE WITH INCREASE IN VELOCITY
100,000 THRUST HP
75,000 THRUST HP
61,000 THRUST HP
42,000 THRUST HP
5,000 THRUST HP
POWER REQUIRED FOR LEVEL FLIGHT
EXAMPLE OF POWER REQUIRED FOR 20,000 POUNDS, HYPOTHETICAL AIRPLANE FLYING AT 40,000 FEET (ASSUMING CONVENTIONAL ARRANGEMENT)
VELOCITY—MPH
SUBSONIC
SUPERSONIC
CONVENTIONAL AIRFOIL
PRESENT HIGH-SPEED AIRFOIL
SPEED OF SOUND AT 40,000 FT. 664 MPH
SPEED OF SOUND AT SEA LEVEL 764 MPH
PROBABLE AIRFOIL SHAPE
VELOCITY—FEET PER SEC
DIRIGIBLE
BALLOON
HELICOPTER
RECIPROCATING ENGINE AND PROPELLER
TURBINE COMPRESSOR
RECIPROCATING ENGINE AND PROPELLER + EXHAUST DRIVEN SUPERCHARGER
TURBINE COMPRESSOR JET
FUEL OXIDIZER
PROFESSOR GODDARD TYPE
POWDER-TYPE ROCKET MOTORS
METEOR
VELOCITY OF METEOR APPROACHING EARTH IN PARABOLIC PATH: 25,000 MPH MAXIMUM POSSIBLE APPROACH VELOCITY: 180,000 MPH
WIND
PROPELLER IMPROVES TAKEOFF AND LOW-SPEED OPERATION
COMPRESSOR
COMBUSTION CHAMBER
TURBINE
RECIPROCATING ENGINE AND PROPELLER + JET-TYPE EXHAUST
TURBINE COMPRESSOR JET + PROPELLER
COMPRESSOR OBTAINED BY RAM
FUEL JETS
COMBUSTION CHAMBER
ATHODYD
ROCKET PROJECTILE
PROJECTILE
AIR BREATHING ENGINES BURNING FUEL-AIR MIXTURE
SELF-CONTAINED FUEL OPERATING INDEPENDENTLY OF ATMOSPHERE
MONTGOLFIER
1750
LIGHTER THAN AIR
LEONARDO DA VINCI
1500
VERTICAL FLIGHT
WRIGHT BROTHERS
1903
FIRST POWER FLIGHT
HERO'S AEOLIPILE
APPROXIMATELY 100 AD
STEAM TURBINE, GAS TURBINE, AND SO FORTH
LEDUC
1933
NOT FLOWN
CHINESE
1300
GUNPOWDER

INSTITUTE ACTIVITIES

North Eastern District Meeting to Be Held in Buffalo, April 24-26

The Niagara Frontier Section will be host to a three-day meeting of the North Eastern District and Student Branch convention to be held in Buffalo, N. Y., April 24–26, 1946. Meeting headquarters will be in the Hotel Statler. As this is the first postwar meeting of the District, the local committee has arranged an exceptionally complete program of both professional and social events, together with inspection trips, to make the meeting an outstanding one.

TECHNICAL SESSIONS

During the three days of the meeting, eight technical sessions will be held on the following timely subjects: power systems, transmission and distribution, electronics, aircraft, industrial applications, aircraft and transportation, lighting, and communication and war developments. In addition, there will be a conference on quality control and a student conference and technical meeting, at which papers will be presented by the students.

INSPECTION TRIPS

At the conclusion of the technical sessions on Friday afternoon inspection trips will be made to power stations and industries, where the equipment which was described in the papers may be seen in operation. Among the places to be visited are the Cornell Aeronautical Laboratory at the Curtiss-Wright Plant, Huntley Station, Schoelkopf Station, one of the aircraft plants, and the Bethlehem Steel Plant.

ENTERTAINMENT

On Wednesday evening a social hour and informal banquet will be held in the ballroom of the Hotel Statler and on Thursday evening the dinner and smoker will be held. There will be an opportunity for dancing every evening. A luncheon for the women has been arranged for Wednesday to be followed on Thursday afternoon by a visit to Niagara Falls and dinner. With travel by car again possible a large turnout of women is expected.

HOTEL RESERVATIONS

Members should make their own hotel reservations by writing directly to the hotel preferred. For convenience a room reservation card for the Statler Hotel was sent to members within the District. In Table I are the rates for the Statler Hotel and also for several of the other nearby hotels.

Table I. Hotel Rates

Hotels	Single Rooms	Double Rooms
Statler, Headquarters Hotel	$3.30–$6.60	$5.50–$11.00
Lafayette	3.50 up	4.50 up
Touraine	3.00 up	5.00– 7.50
Buffalo	2.50– 4.00	4.00– 8.00
Sheraton	3.00– 3.50	5.00– 6.00
Ford	1.50– 2.50	2.50– 5.00

Make reservations at once! Other meetings on the same date will tax hotel accommodations.

ADVANCE REGISTRATION

Please register in advance. This will assist the registration committee and save time on arrival at the meeting. A registration fee of two dollars will be charged all nonmembers with the exception of En-

Future AIEE Meetings

South West District Meeting
San Antonio, Tex., April 16–18, 1946

North Eastern District Meeting
Buffalo, N. Y., April 24–26, 1946

Southern District Meeting
Asheville, N. C., May 14–16, 1946

Summer Convention
Detroit, Mich., June 24–28, 1946

Pacific Coast Convention
Seattle, Wash., in week of August 26–30, 1946

Great Lakes District Meeting
Fort Wayne, Ind., September 25–27, 1946

Kleinhans Music Hall (left) and the City Hall in Buffalo, N. Y., where the North Eastern District meeting is being held

Technical Program and Meeting Features

● **PAMPHLET** reproductions of authors' manuscripts of the numbered papers listed in the program may be obtained as noted in the following paragraphs.

● **ABSTRACTS** of numbered papers appear on pages 174–5 of this issue.

● **PRICES** and instructions for procuring advance copies of these papers accompany the abstracts. Mail orders are advisable, particularly from out-of-town members, as an adequate supply of each paper at the meeting cannot be assured. Only numbered papers are available in pamphlet form.

● **PAPERS** regularly approved by the technical program committee ultimately will be published in "Transactions"; many will appear in "Electrical Engineering."

Wednesday, April 24

8:30 a.m. Registration

9:30 a.m. Power Systems

46-99 ACO.♯ A 1,000-Kva Mobile Substation and Its Service Record. **M. W. Bardwell**, Central New York Power Corporation

CP.* Electrical-Mechanical Features of Jennison Steam Generating Station and Transmission-Line Connections. **W. W. Perry, Walter Greacen, III**, New York State Electric and Gas Corporation

CP.* Southeast Emergency and Power Pooling in 1941. **C. W. Mayott**, The Hartford Electric Light Company

CP.* Automatic Control of Large Synchronous Condensers. **M. J. Brown**, Westinghouse Electric Corporation

12:00 noon. District Executive Committee Luncheon

1:00 p.m. Ladies' Luncheon

2:00 p.m. Transmission and Distribution

46-100 ACO♯. Control of Frequency and Tie-Line Loads on the Niagara–Hudson System and Interconnections. **B. S. Rice**, Buffalo Niagara Electric Corporation

DP.** Theoretical Approach to Tie-Line Frequency Control. **R. Brandt**, New England Power Company

46-93 ACO.♯ Incremental Transmission-Line Losses. **W. P. Wilder**, Buffalo Niagara Electric Corporation

CP.* Primary and Secondary Cable Developments. **R. B. McKinley**, General Electric Company

46-84. Geometric Mean Distances for Rectangular Conductors. **H. B. Dwight**, Massachusetts Institute of Technology

2:00 p.m. Electronics

46-88 ACO.♯ Application of the Electronic Oscillator to Measurement and Control. **P. M. Hackett**, E. I. duPont de Nemours and Company, Inc.

DP.** One-Millionth-Second Radiography and Its Application. **C. M. Slack**, Westinghouse Electric Corporation

DP.** High Vacuum Leak Testing with Mass Spectrometer. **W. G. Worcester, E. G. Doughty**, General Electric Company

CP.* Induction and Dielectric Heating. **Kennard Pinder**, E. I. duPont de Nemours and Company, Inc.

6:00 p.m. Social Hour and Banquet

Thursday, April 25

9:30 a.m. Aircraft

46-85 ACO.♯ Electric Equipment for Cornell Variable-Density Wind Tunnel. **C. C. Clymer, M. A. deFerranti**, General Electric Company

46-86 ACO.♯ Electric Equipment Required in the Modern Six-Component Wind-Tunnel Balance System. **H. O. Cox**, Cornell Aeronautical Laboratory

46-87 ACO.♯ Radio-Telemetering for Testing Aircraft in Flight. **C. L. Frederick**, Cornell Aeronautical Laboratory

CP.* Dive Testing Aircraft by Radio Control. **R. M. Stanley, R. H. Frost**, Bell Aircraft Corporation

9:30 a.m. Industrial Applications

46-92 ACO.♯ A Hot-Strip-Mill Flying-Shear Control Providing an Electric Tie Between Mill and Shear. **J. E. Sowers**, Bethlehem Steel Company; **V. A. Leitske**, General Electric Company

CP.* Spectrograph Analysis of Steel. **T. S. Jackson**, Bethlehem Steel Company

DP.** Arc Furnace Switching. **L. W. Long**, Allis-Chalmers Manufacturing Company

DP.** Theoretical Conditions Existing in Single-Phase Electric-Furnace Circuits. **J. J. Pannabaker**, Vanadium Corporation of America

12:00 noon. General Luncheon

Address: Organization of Engineering Profession. **W. S. Hill**, General Electric Company

2:00 p.m. Ladies' Visit to Niagara Falls, followed by Dinner

2:00 p.m. Aircraft and Transportation

CP.* Automatic Instrumentation for Recording Flight-Test Data. **E. T. McMahon**, Bell Aircraft Corporation

46-89 ACO. Hit-Indicator Equipment for Gunnery Training with Frangible Bullets. **K. E. Burnham**, Bell Aircraft Corporation

46-90. Modern Double-Reduction Traction Motor. **Lanier Greer**, General Electric Company

46-91. High-Voltage Ignitron Rectifiers and Inverters for Railway Service. **J. L. Boyer, C. G. Hagenaick**, Westinghouse Electric Corporation

2:00 p.m. Lighting

CP.* Lighting for Traffic Safety. **H. W. Osborne**, traffic advisor, Board of Safety, City of Buffalo

DP.** Bactericidal Effect of Ultraviolet Radiation. **H. C. Rentschler**, Westinghouse Electric Corporation

3:00 p.m. Conference on Quality Control

Panel Discussion: **Professor Martin Brumbaugh**, chairman, University of Buffalo; **Alfred J. Winterhalter, Jr.**, Colonial Radio Corporation; **J. Manuele**, Westinghouse Electric Corporation; **D. C. Stewart**, Buffalo Niagara Electric Corporation

6:00 p.m. Dinner and Smoker

Friday, April 26

9:30 a.m. Communication and War Developments

CP.* Coaxial Buffalo–Cleveland Telephone Cable. (Tentative.) American Telephone and Telegraph Company

CP.* Radar Demonstration. **E. F. Herzog**, General Electric Company

DP.** The Radio Proximity Fuse. **L. G. Hector**, National Union Radio Corporation

DP.** Relays of the Sensitive Instrument Type in Target Seeking and Proximity Weapons. **A. H. Lamb**, Weston Electrical Instrument Company

DP.** The A B C of Servomechanisms. **S. W. Herwald**, Westinghouse Electric Corporation

10:00 a.m. Student Conference and Technical Meeting

Student Paper Presentations

DP.** Development Within the Profession. **Everett S. Lee**, General Electric Company

12:00 noon. Student Counselors' and Branch Chairman's Luncheon

Afternoon. Inspection Trips

*CP: Conference paper; no advance copies are available; not intended for publication in *Transactions*.

**DP: District paper; no advance copies are available; not intended for publication in *Transactions*.

♯ACO: Advance copies only available; not intended for publication in *Transactions*.

rolled Students and immediate families of members.

COMMITTEES

T. J. Brosnan, chairman, J. D. Hershey, secretary and treasurer, C. H. Anderson, M. Dewey, J. M. Geiger, R. G. Harper, R. T. Henry, W. S. Hill, R. J. W. Koopman, C. McIntosh, H. L. MacIntyre, J. H. Milbyer, L. J. Murphy, J. F. Oehler, W. K. Parks, G. M. Pollard, N. B. Phillips, J. L. Scanlon, J. E. Sowers, Jr., H. B. Vidal, H. E. Weiss, L. K. Yerger, G. A. Zehr.

South West District Meets In San Antonio, April 16–18

All is in readiness for the South West District Meeting and Student Branch Convention to be held in San Antonio, Tex., April 16–18, 1946. Headquarters for the meeting will be in the Plaza Hotel. A program comprised of nine sessions, including two general sessions and a student session, has been arranged. Among the features of these sessions will be a discussion of Institute activities under the direction of the committee on planning and co-ordination and a special session on electrical problems in Mexico conducted entirely by members from the Mexico Section. On the social side a full program of dinners with entertainment, sport, and trips, as well as special events for the women, will assure a busy and enjoyable time for all who attend. The complete program and details were announced in the March issue of *Electrical Engineering*, pages 120–1.

Southern District to Meet in Asheville, N. C., May 14–16

Asheville, high in the mountains of North Carolina, will be host to a three-day meeting of the Southern District and Student Branch convention, May 14–16, 1946. Headquarters will be in the Grove Park Inn.

In addition to the opening session a program of three technical sessions has been arranged and papers will be presented which are of special interest to electrical engineers in the South. Another session will be held at which papers will be presented by students and a conference on student activities also will take place. AIEE President W. E. Wickenden will address the meeting on the first evening and on the second evening a talk will be given by Commander J. F. Hellweg, United States Navy (retired), formerly of the United States Naval Observatory. Inspection trips have been arranged to visit a paper mill and a rayon plant, as well as the Glenville hydroelectric plant and the Cliffside steam plant.

On Monday evening preceding the opening of the meeting the following events have been arranged: Dinner at Grove Park Inn at 7:00 p.m.; Southern District executive committee meeting; Vice-President H. B. Wolf, presiding, at 8:00 p.m.; and an informal discussion of Institute affairs; Vice-President J. F. Fairman, presiding, at 8:30 p.m.

ADVANCE REGISTRATION

Members of the District, who will receive an advance registration card, should register in advance by filling in and mailing the card. A two dollar nonmember registration fee will be charged all nonmembers except Enrolled Students and the immediate families of members.

HOTEL ACCOMMODATIONS

Members should make their own hotel reservations by writing directly to the hotel preferred. It is advisable to make reservations as early as possible.

COMMITTEES

General:
J. F. Rader, H. W. Oettinger, *co-chairmen;* C. P. Almon, Jr., P. J. Curtin, J. A. Crisman, Carl W. Evans, S. H. Gates, William Stone Leake, W. E. Lindemann, Otto Meier, Jr., J. A. Rawls, F. T. Tingley, F. C. Weis

Hotel and Registration:
H. H. Gmuz, Jr., *chairman;* W. F. Sanders, C. O. Warren

Transportation and Inspection Trips:
M. F. Leftwich, *chairman;* H. C. Crowley, H. E. Wilson

Attendance and Publicity:
Harold Lampe, *chairman;* F. C. Alexander, W. W. Ballew

Technical Papers:
F. W. Chapman, *chairman;* W. J. Seeley

Finance:
H. B. Robinson, *chairman;* W. H. Kendrick

Sports and Entertainment:
G. O. Baton, *chairman;* Dean H. Davis

Ladies' Entertainment:
Mrs. Howard Strock, *chairman;* five to be appointed

Student Activities:
Otto Meier, Jr., *District chairman;* E. O'Brien, *national chairman*

Tentative Technical Program and Meeting Features

● **PAMPHLET** reproductions of authors' manuscripts of the numbered papers listed in the program may be obtained as noted in the following paragraphs.

● **ABSTRACTS** of papers are expected to be available for the May issue.

● **PRICES** and instructions for procuring advance copies of these papers will accompany the abstracts. Mail orders are advisable, particularly from out-of-town members, as an adequate supply of each paper at the meeting cannot be assured. Only numbered papers will be available in pamphlet form.

Tuesday, May 14

8:30 a.m. Registration
10:30 a.m. Opening session

Address of welcome by the Mayor of Asheville

Remarks by **Vice-President H. B. Wolf**

Remarks by **President-elect J. E. Hobsley**

Talk on Institute Planning by **Vice-President J. F. Fairman**, chairman, committee on planning and coordination

2:30 p.m. Meeting of Board of Directors

2:30 p.m. Symposium on Electric Power in the Textile Industry

DP.* VIEWPOINT OF MANUFACTURER, **W. L. Bross**

DP.* ELECTRIC POWER IN THE TEXTILE INDUSTRY—VIEWPOINT OF DESIGN ENGINEER. **George Wrigley, J. E. Sirrine and Company**

DP.* APPLICATION OF ELECTRIC POWER TO TEXTILE PLANTS AS VIEWED BY THE ELECTRIC UTILITY. **C. G. Mattison, W. K. Harding**, Duke Power Company

DP.* ELECTRONIC HEATING IN TEXTILE MANUFACTURE. **H. T. Smith**, The Girdler Corporation

DP.* PRICE IS A FUNCTION OF WAGES. **F. U. Ross**, Virginia Electric and Power Company

DP.* THE RESPONSIBILITY OF AIEE TO THE HIGH SCHOOL. **W. E. Lindemann**, Tennessee Valley Authority

8:30 p.m. Address by President W. E. Wickenden

Wednesday, May 15

8:30 a.m. Business Meeting, North Carolina Section

9:00 a.m. Student Papers Session

9:00 a.m. Technical Session

46-96. MAINTENANCE OF RECTIFIERS ON ELECTROCHEMICAL INSTALLATIONS. **J. E. Housley, G. M. Hughes**, Aluminum Company of America

DP.* INDUSTRIAL POWER DISTRIBUTION. **R. H. Kaufmann**, General Electric Company

46-97. LIGHTNING PROTECTION FOR INDUSTRIAL PLANTS. **E. W. Beck, J. Z. Linsenmayer**, Westinghouse Electric Corporation

DP.* FACTORS AFFECTING RANGE OF RADAR SETS. **L. R. Quarles, W. M. Brownsale**, University of Virginia

2:00 p.m. Inspection Trips

Ecusta Paper Corporation
Glenville Hydroelectric Plant
Cliffside Steam Plant

8:30 p.m. Evening Session

Presentation of student prizes by **E. W. O'Brien**, chairman, committee on Student Branches
Talk by **Commodore J. F. Hellweg**, United States Navy (retired), formerly of United States Naval Observatory

Thursday, May 16

8:30 a.m. Conference on Student Activities
9:00 a.m. Technical Session

DP.* 115-KV CABLE INSTALLATION IN ATLANTA. **R. O. Loomis**, Georgia Power Company

46-98. SELECTIVE GROUND RELAYING OF AN UNGROUNDED SYSTEM. **E. P. Miller**, South Carolina Electric and Gas Company

DP.* CENTRALIZED CONTROL OF A POWER SYSTEM. **Perry Peterson**

DP.* T.V.A. COMMUNICATIONS FACILITIES. **T. deWitt Talmage**, Tennessee Valley Authority

First-prize student paper

2:00 p.m. Inspection Trips

Enka Rayon Corporation
Glenville Hydroelectric Plant
Cliffside Steam Plant

*DP.: District paper; no advance copies are available; not intended for publication in *Transactions*.

Philadelphia Gains 1,000th Member

Announcement that the membership of the Philadelphia AIEE Section has reached 1,000 recently was made by M. L. Lehman (M '36) chairman of the Section's membership committee.

The 1,000th member is Winfield A. Scott (A '38) now of the Bell Telephone Company of Pennsylvania. Until this time Mr. Scott, who had been serving a a lieutenant in the United States Army, had been on the AIEE military inactive list, and he has just resumed his active membership status.

Grove Park Inn, headquarters for the Southern District meeting, Asheville, N. C., May 14–16

AIEE Board of Directors Meeting

The regular meeting of the board of directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on Thursday, January 24, 1946.

Upon recommendation of the committee on planning and co-ordination and the special committee on registration of engineers, the board adopted a resolution that the AIEE recognizes the registration of engineers as a continuing practice and endorses the Model Law for Professional Engineers and Land Surveyors, as adopted in 1943 and amended in 1945 by a joint committee of several engineering societies, as the widely accepted basis of its administration, and that the Institute endorses these procedures as well established. Also, upon recommendation of these two committees, the board authorized the establishment of a standing committee on registration of engineers, to replace the special committee. The possibility of assigning other functions to the committee was suggested, and the committee on planning and co-ordination was requested to report recommendations concerning the scope of the committee. The special committee on registration of engineers was continued until the appointment of the standing committee.

The establishment of joint Student Branches of AIEE and the Institute of Radio Engineers wherever desired was authorized, as recommended by the committee on Student Branches, and to that committee was delegated the responsibility of carrying out the policy.

Executive committee actions at an evening session on January 21, 1946, were approved as follows:

Approval of recommendations adopted by the board of examiners at its meeting on December 13, 1945.

Appointments as follows:

J. W. Barker and I. Melville Stein as AIEE representatives on the Council of the American Association for the Advancement of Science for the calendar year 1946.

N. Thornton as Local Honorary Secretary of the Institute for Northern India for the unexpired term, ending July 31, 1946, of V. F. Critchley, resigned.

J. M. Standring, Jr., as one of the representatives of AIEE on the American Co-ordinating Committee on Corrosion for the remainder of the current administrative year, to succeed E. B. King, resigned.

Appropriation expenditures, reported by the chairman of the finance committee, were approved, as $25,920.24 in December and $32,449.42 in January.

It was decided to hold the 1946 annual meeting of the Institute in Detroit, Mich., on Wednesday, June 26.

Upon recommendation of the committee on planning and co-ordination, the winter convention, New York, N. Y., January 27–31, 1947 and the Middle Eastern District meeting, Dayton, Ohio, fall of 1947, were authorized.

Vice-President M. S. Coover was appointed to attend the presentation of the Washington Award to Doctor Vannevar Bush, February 20.

An invitation to be represented at the inauguration of Arthur Holly Compton as Chancellor of Washington University, on February 22, was referred to the President with the understanding that if unable to attend himself he would appoint the chairman of the St. Louis Section.

A bequest of $10,000 from the late W. S. Barstow was accepted, and the execution of the necessary legal steps for its payment was authorized.

It was decided to hold the May meeting of the board of directors in Asheville, N. C., on the afternoon of Tuesday, May 14, during the Southern District Meeting.

The following amendments to the bylaws, recommended by the committee on constitution and bylaws, were adopted:

Section 48. Amended to read as follows, to conform with the new method of allotting funds to the Sections adopted by the board November 2, 1944: Each Section shall conduct its affairs in such a manner as to require for its maintenance only such financial support by the Institute as is consistent with the activities carried on by that Section. Except upon the request of a Section stating specific reasons therefor, and with the approval of the Sections and finance committees, the appropriation of Institute funds during any year shall not exceed in the aggregate a sum to be determined as follows:

(a). Two-hundred dollars basic allotment

(b). One dollar and twenty cents for each Institute member within the Section territory on August first

(c). An additional amount for a larger number of regularly scheduled Section, Subsection, and technical group meetings held during the preceding fiscal year (ending April 30) as follows:

1. Twelve to 17 meetings, 25 dollars
2. Eighteen to 23 meetings, 50 dollars
3. Twenty-four or more meetings, 75 dollars.

The Treasurer and Secretary of the Institute shall forward in October of each year to the Secretary of each Section one-half of the sum to which the Section is entitled under this bylaw, less any unexpended balance in the funds provided by the Institute during the preceding year and which shall be considered as part of the payment for the current year. An accounting shall be made to the finance committee of the Institute, through the Secretary, when these funds have been expended, whereupon the

Part of the Detroit Setting for the Summer Convention

The above view of the Ford Rouge Plant is indicative of the industrial background of the forthcoming summer convention to be held in Detroit, Mich., June 24–28, 1946, with headquarters at the Statler Hotel.

Sessions are being planned covering electric welding, electronic devices and basic circuits, electronic applications, industrial control devices, management and quality control, power transmission and distribution, and cables. A symposium on grounding is planned, sponsored by the committee on safety. It is expected also that technical conferences will offer opportunities for the discussion of such subjects as servomechanisms, supervisory control of air switches, automatic switching of capacitor banks, and teaching aids for electronic instruction.

Inspection trips being planned include: The Ford River Rouge Plant, where a typical cross section of modern automotive production may be seen, including all phases from foundry and steel mill to assembly and finishing lines; U. S. Rubber Company plant, where the intricate and fascinating sequence of operation involved in the modern manufacture of automobile tires may be viewed; General Motors Proving Ground, to observe a typical example of the exacting tests which the automotive industry prescribes for its products; Edison Institute Museum at Greenfield Village, founded and endowed by Henry Ford, which represents an extensive cross section of human and technical history. Many entertainment features are planned.

Under the direction of S. M. Dean, chairman, T. G. Glenn, vice-chairman, and W. F. Wetmore, secretary-treasurer, the following committee chairmen, with their respective committees, are functioning to assure that the Detroit convention will be long remembered: M. A. Bergdahl, Hospitality; D. D. Chase, Sports; H. W. Collins, Hotels; A. J. Koetsier, Publicity; A. E. Kreigsmann, Meetings and Papers; W. J. Piper, Information and Transportation; V. J. Snyder, Finance; R. C. Spaulding, Inspection Trips; F. R. Temple, Registration; and Mrs. M. A. Bergdahl, Ladies' Hospitality.

The full program is scheduled to be published in the May issue of *Electrical Engineering*.

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balance of the appropriation for the year shall be sent to the Secretary of the Section for which an accounting will be made at the end of the year.

Section 65. Amended by the addition to the list of technical committees of the name of the committee on industrial control devices, established by authority of the board of directors on May 29, 1945.

Map portraying the Geographical Districts of the AIEE, in conformity with action of the Board of Directors on May 29, 1945, transferring the Mexico Section from District 3 to District 7, changed as follows:

In the statement of the New York City (District 3) territory, the parenthetical expression "(Canada excepted)" changed to "(Canada and Mexico excepted)."

The heavy boundary line between Texas and Mexico moved to indicate that Mexico is a part of District 7.

Throughout the bylaws, the word "national" deleted wherever it occurs in the titles of officers, committees, and meetings, to conform with the constitution as amended in 1945.

In view of the fact that the income from the Edison Medal Fund has been insufficient in recent years to cover the increased cost of the Edison Medal due to the high cost of gold, plus taxes, the board voted to establish the policy of paying from the Institute treasury the amount of the cost of the Edison Medal in any year which is in excess of the income from the Edison Medal Fund, thus making possible, though not mandatory, an annual award of the medal.

The board authorized the usual travel expense allowance for delegates from District 8 and the University of British Columbia Branch to a joint conference on Student activities to be held in District 9 during the 1946 Pacific Coast convention, in Seattle, Wash., August 27–30.

Other actions taken included:

Minutes were approved of the meeting of the board of directors on October 18, 1945, and of the meeting of the executive committee on December 11, 1945.

Recommendations adopted by the board of examiners at a meeting on January 17, 1946, were approved. The following actions were taken upon recommendation of the board of examiners: 6 applicants were transferred to the grade of Fellow; 25 applicants were transferred and 57 were elected to the grade of Member; 206 applicants were elected to the grade of Associate; 364 Student members were enrolled.

Those present included:

President—W. E. Wickenden, Cleveland, Ohio. *Past-presidents*—N. E. Funk, Philadelphia, Pa. *Vice-presidents*—C. B. Carpenter, Portland, Oreg.; M. S. Coover, Ames, Iowa; F. F. Evenson, San Diego, Calif.; J. F. Fairman, New York, N. Y.; E. S. Fields, Cincinnati, Ohio; R. T. Henry, Buffalo, N. Y.; F. L. Lawton, Montreal, Quebec, Canada; L. M. Robertson, Denver, Colo.; R. W. Warner, Austin, Tex.; Herman B. Wolf, Charlotte, N. C. *Directors*—P. L. Alger, Schenectady, N. Y.; J. M. Flanigen, Atlanta, Ga.; C. M. Laffoon, East Pittsburgh, Pa.; M. J. McHenry, Toronto, Ontario, Canada; C. W. Mier, Dallas, Tex.; S. H. Mortensen, Milwaukee, Wis.; W. B. Morton, Allentown, Pa.; J. R. North, Jackson, Mich.; D. A. Quarles, New York, N. Y.; W. C. Smith, San Francisco, Calif.; W. R. Smith, Newark, N. J. *Treasurer*—W. I. Slichter, New York, N. Y. *Secretary*—H. H. Henline, New York, N. Y.

Planning Subcommittee Issues Progress Report On Study of Organization of Engineering Profession

Full text of a progress report prepared by the AIEE planning and co-ordination committee's professional activities subcommittee; T. G. LeClair (F '40) chairman, M. S. Coover (F '42), W. S. Hill (M '30), B. D. Hull (F '39), and F. E. Sanford (M '34)

Evolutionary developments in engineering, membership in the Institute, and the activities of the Institute all have expanded so rapidly in recent years that the committee on planning and co-ordination was given the assignment of analyzing all the Institute's activities in order to determine in what way it could be of greater service to the members. The committee on planning and co-ordination appointed two subcommittees to study two phases of the problem. The technical activities subcommittee was assigned the task of studying the Institute's technical activities, such as technical papers, Standards, transactions, technical committees, and other related activities as well as the corresponding activities in other societies. The professional activities subcommittee was assigned the task of studying the Institute's place in relation to such subjects as compensation, professional ethics, engineering registration, and all other activities having to do with the professional activities of engineers and their contacts with the public in general.

It was immediately apparent that nearly all professional activities are common to all branches of the engineering profession and, therefore, affect all the existing engineering societies and their relations with each other. Consequently it was found necessary to analyze the broader problem of organizing to handle professional activities for all engineering societies, not merely the AIEE.

Many suggestions have been considered by the subcommittee for means of improving the efficiency of engineering society activities along professional lines. Most of the problems are so interrelated that the subcommittee decided to consider the entire field and approach first the ideal method of organizing the engineering profession with the thought that later consideration would be given to practical compromises if agreement could be reached on a common goal. A small subcommittee having limited contacts and not knowing the desires of 25,000 members did not feel competent to recommend directly a general approach to the organization question without learning the wishes of a larger body of members. Therefore, the subcommittee has prepared brief discussions on four methods for organizing the engineering profession, and submits them for general discussion and comments from the members. None of the four plans described is intended as a finished product. The description is solely for the purpose of stimulating comment and obtaining a cross section of members' opinion before the subcommittee undertakes further detailed work.

Editor's Note: Presented for purposes of discussion, the accompanying progress report of the professional activities subcommittee represents the subcommittee's initial effort and interpretation of its assignment. As variously reported in ELECTRICAL ENGINEERING during recent months, the AIEE committee on planning and co-ordination was assigned the task of studying AIEE activities with a view toward determining possible ways and means of extending or improving them in the interest of better service to the membership. The planning and co-ordination committee divided this job, and established a technical activities subcommittee to cover the field indicated by its title, and a professional activities subcommittee to cover all other activities and intersociety relationships.

The substance of this progress report was presented and discussed informally at an afternoon session during the recent winter convention. The present expressed intention of the subcommittee is to stimulate active membership discussions of these proposals in all Sections during the immediately forthcoming months, thus laying the foundation for a further general discussion which is contemplated for the summer convention conference of officers, delegates, and members.

It seems desirable to emphasize that the purpose of this presentation is not to promote the quick choice of any one "plan" as against any other "plan," but rather to stimulate thought and discussion through which to determine and to clarify membership understanding and desires as to basic AIEE objectives.

The recommendation of the subcommittee is that these plans be published in *Electrical Engineering* and that a questionnaire be made available to all Institute members having a special interest in this problem, and particularly to members of the executive committees of all Sections. The answers to the questionnaire will be used to determine the future course of action of the subcommittee.

This preliminary report may appear to parallel, if not to conflict, with activities which are being undertaken by other groups. The broadest activity under way at the present time is under the sponsorship of the Engineers Joint Council, an organization with representatives from the following engineering societies: AIEE, American Society of Mechanical Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Civil Engineers, American Institute of Chemical Engineers. This council has appointed 15 men to committees which have been active for some months but have issued no reports. It is hoped that information obtained through the activity of the AIEE subcommittee will be a valuable guide to the Institute itself, and also will serve as a reference to the committees representing the several other engineering societies.

The four plans presented herewith are not intended to be the only possible plans available. They have been selected primarily because they represent a variety of approaches to the problem. It is suggested that members keep an open mind and consider all plans before concluding whether one of them or some other appears to be the most practical for creating a strong united engineering profession.

Of the four plans, one, plan *A*, covers only the electrical engineering field. A plan once operating effectively in this field might be expanded to cover all fields of engineering. The other three plans, *B*, *C*, and *D* cover the entire engineering field and have as their objective creation of a strong united engineering profession.

A brief description of each of the plans follows.

Plan *A* proposes consolidating the existing electrical engineering societies only into a new *American Association of Electrical Engineers* which would unite those practicing in all fields of electrical engineering to be more effective than is possible with the several societies now in existence.

Under this plan, the initial unifying efforts are confined to the field of electrical engineering. Its proponents hope that the experience gained in creating a functioning American Association of Electrical Engineers will indicate how the plan could be expanded to accomplish the broader objective of creating an all-inclusive engineering society and that this process of development might result in an all-inclusive engineering society that would function successfully for all those practicing engineering regardless of the field.

Plan *B* proposes that the existing engineering societies continue to function in technical matters and that a separate autonomous *Engineering Profession Society* of which all engineers would be members should carry on nontechnical or general activities of interest to engineers.

Plan *C* proposes a federation of council of all existing engineering societies so that *The Federated Engineering Societies* would provide a single channel for consideration

and action on all technical and professional matters of interest to engineers.

Plan *D* proposes the setting up of a new *American Society of Engineers* into which would be incorporated many of the existing societies. This society would have all engineers as members and would function in all technical and professional activities involving engineers.

These plans were presented and discussed at the winter convention in New York, N. Y., January 1946.

HISTORICAL INTRODUCTION

In considering the need for action to unify the engineering profession, it might be well to review how engineering developed and how there was a corresponding development of engineering societies. Rather than cover the entire field of engineering, the electrical engineering field will be reviewed as being, in general, representative of similar developments in other branches of engineering.

The electrical industry, which was founded by Thomas Alva Edison in 1882 when he gave to the City of New York and to the world the first electric lighting system, still is expanding over ever-widening areas and apparently with limitless boundaries. The growth of the electrical industry has been rapid and phenomenal. It has been developed to the point where it touches in one way or another the lives of all peoples and nations.

Just as Edison gave to the world the electric power industry, so did Morse, Bell, Marconi, and others give electrical communication systems in order that intelligence might be transmitted by faster means than the pony express or wheel-borne vehicles.

Technical advances that were made in the electrical field during the period of World War II have been enormous. It is doubtful if the same progress would have been made under normal conditions in a quarter of a century. The fact remains that today there are many specialized areas within the electrical engineering field. There are so many individuals engaged in those areas that already there is evidence of further expansion of technical societies or organizations so that engineers may meet on common technical grounds for their personal and professional development.

As a result of the work of Edison and others, there soon came the desire for an association of electrical engineers, and in 1884 the American Institute of Electrical Engineers was founded. It fulfilled the immediate needs of the electrical engineers in the power and the communication fields. The Institute grew and it prospered because it rendered a useful service.

It was not long before further specialization began to develop the desire of men thus engaged to come into closer touch with one another for more effective public service; for the reading and discussion of appropriate papers; and for the advancement of engineering and scientific knowledge in their respective professional areas. So it was that the Electrochemical Society was founded in 1902.

With the rapid adoption of electric lighting, the development and manufacture of new and improved lighting units, and the establishment of lighting standards, a demand developed among those working in these fields to band together. The Illuminating Engineering Society consequently was formed in 1906.

Concurrently with the commercialization of radio came an ever-growing need for engineers in that vocation to work in closer harmony. This industry was creating a demand for and absorbing more and more electrical engineers with each passing year. It was only natural for those engineers to want to organize among themselves. The pressure for organization was great, the need was apparent, and the Institute of Radio Engineers became a reality in 1912.

CURRENT DEVELOPMENTS

The tremendous development and application of electronic devices within recent years has created new specialized groups and the possibility of new corresponding societies being formed. It is well known that the first National Electronics Conference held in Chicago in 1944 was planned for an expected attendance of around 500 and that approximately 2,200 were in attendance. The results in terms of interest were overwhelming and the potentialities of another group of electrical engineers banding together are great. Those interviewed on the subject agreed almost without exception that the formation of an organization covering the field of electronics is likely.

Aviation electrical engineers are growing in numbers, and increasing numbers of electrical engineers are being engaged in other highly specialized fields of electrical engineering. To what end may all this lead? Will an expanding number of corresponding societies provide greater professional benefits than a well-co-ordinated single over-all organization? The technical gains achieved through specialized societies may be outweighed by the accompanying social and economic handicaps. The engineer needs, and rightfully deserves, to reap all possible advantages.

SIMILARITY OF ENGINEERING ORGANIZATIONS

There is a marked similarity among many of the existing engineering organizations in the various fields of engineering, as well as among those in a single specialized field.

Many engineers hold membership, and quite a few hold office and committee assignments, in two or more of the present national engineering organizations. These similarities may indicate a way to unite all engineers in some single organization.

Many of the societies have general committees which carry on similar activities and even may have the same name. The following are some of these committees: executive, finance, constitution and bylaws, publication, advisory policy, membership, board of examiners, Sections, nominations, education, and awards.

Since each society functions in its own technical field, there is less similarity among their technical committees except for research, Standards, and like committees. The technical interests are, however, so interrelated that all engineers should consider themselves members of one engineering profession.

FUNCTIONS OF ENGINEERING ORGANIZATIONS

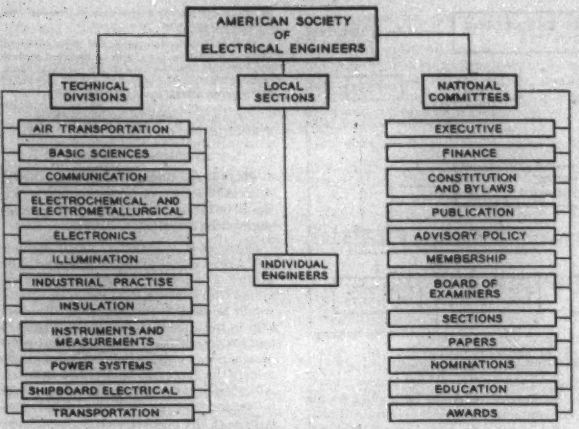
Engineering societies seem to have been organized for the purpose of carrying on one or more of the following functions:

(*a*). *Technical advancement or "the advancement of the theory and practice of (a particular branch of) engineering."* During more than 300 years, men interested in science have been meeting to exchange views on their observations and experiences and to discuss their problems. These "town meetings" of technological progress continue to provide engineers and scientists of our generation contact with the current work of others. They make possible a continuation of the individual's education in his chosen field and encourage interest in new developments. The traditional purpose of engineering organization is to provide a convenient path for the expeditious flow of technical information among the members and to broaden their interests in fields other than their own.

(*b*). *Engineering education.* Studies of engineering training and the development of plans for student selection and guidance are matters for joint consideration by engineers in every line of endeavor as well as by engineers in academic life. The professors may conduct the formal educational process but practicing engineers should interest themselves in the content and standards of formal engineering education, in the selection and guidance of suitable candidates for an engineering education, and in the postgraduate training and professional development of the young engineers.

(*c*). *Advancement of the profession.* It is not axiomatic that a unified association of practitioners automatically will place a profession on a pedestal of dignity and prestige. Nor does it follow that licensing or registration by the state in themselves will assure appropriate public recognition of a profession. But it does seem that these may be among the factors which would further the advancement of the profession. Other factors might be a uniform code of ethics and canons of practice, a common recognition by the profession of what constitutes full professional status, assistance to engineering graduates in attaining that status, greater responsibility for legislation affecting the standards and the practice of the profession, assistance to members of the profession in obtaining employment, establishment of schedules of fees and salaries for professional services commensurate with the value of such services, and active support of the individual members in maintaining the integrity, dignity, and independence of the profession.

(*d*). *Public service.* Events of recent years have served to emphasize the important part which engineers as individuals and as organized groups can and should play in public affairs. It would seem reasonable to expect that engineers should



Plan A organization

be able to apply their talents for the effective and efficient organization of men and materials to the problem of rendering a disinterested public service as a professional group at the several levels of government. Such service should be rendered in times of peace as well as during national emergencies. Definite avenues for co-operation with government agencies should be established and used.

THE PROBLEM

How should the engineering profession be organized to carry out the foregoing functions to best advantage? The four plans discussed are intended to attain the same broad objectives. The differences are only in method. Which will work best? Which can be put into operation most expeditiously? What combination of these or what other plan would serve the purpose better? What are the advantages and disadvantages of each? The committee is seeking answers to these and related questions.

PLAN A. AMERICAN ASSOCIATION OF ELECTRICAL ENGINEERS

This plan proposes the consolidation of existing electrical engineering societies only into a new single unified society which for the purposes of this discussion will be called an American Association of Electrical Engineers. All engineers practicing in any field of electrical engineering then would be eligible to become members of the same society. Deliberations and actions taken would be on the basis of what would be most beneficial for all electrical engineers.

The experience gained in establishing a functioning American Association of Electrical Engineers might indicate how an all-inclusive Engineering Society could be created that would serve all engineers and bring about a strong united engineering profession.

Organization Required. An American Society of Electrical Engineers should be organized to get maximum individual member participation. This would require division of the Society into as many technical groups as would be necessary to cover the main technical fields which now exist or which might exist in the future.

Attaining Organization. Organizing an American Society of Electrical Engineers presumably would require dissolving the existing national electrical engineering organizations after merging all their activity in the new American Society of Electrical Engineers.

This merging would be accomplished by having a joint committee composed of representatives of the American Institute of Electrical Engineers, Institute of Radio Engineers, Illuminating Engineering Society, Electrochemical Society, and of groups which seriously may be considering organizing, such as those in the electronic field.

The general committee would be supplemented by having similar common committees, such as executive, financial, membership, publication and others, sit in joint conference and conscientiously try to develop a unity that would enable the American Society of Electrical Engineers to function properly.

These committees would determine the grades of membership, technical publications, and other matters on which there would have to be agreement in forming the new American Society of Electrical Engineers.

In this "Constitutional Convention" certain sovereign rights of the component groups would be surrendered to the new American Society of Electrical Engineers. Then with the dissolution of the component groups, the new American Society of Electrical Engineers would carry on and function for all electrical engineers.

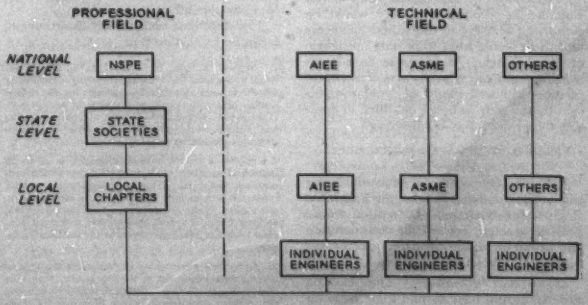
Technical Publications. A publication containing articles of general interest would be given to each member. In addition, each of the technical divisions could have its own separate publication. Any member could subscribe for as many of these as he wished to receive by paying additional fees, which would be based on cost and vary with the amount of approved material each technical division published.

Membership. Grades of membership in the American Society of Electrical Engineers would have to be established which would be available to individuals at a fee to be determined.

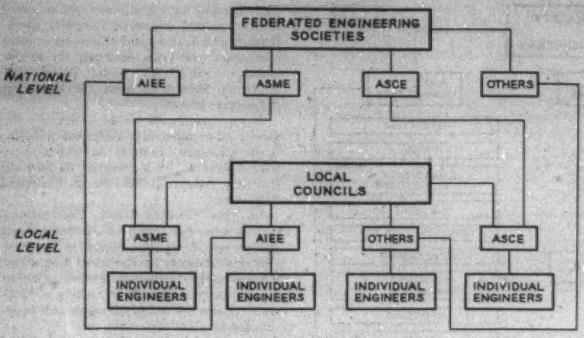
PLAN B. ENGINEERING PROFESSION SOCIETY PARALLELING PRESENT ENGINEERING ORGANIZATIONS

This plan is based on the existing engineering organizations continuing to function in all technical matters and having an Engineering Profession Society carry on those nontechnical or general activities which are of interest to the engineering profession. Broadly, these activities are advancement of the profession as a whole and providing more effective public service.

Organization Required. This Engineering Profession Society should be organized so as to get maximum individual member participation in all matters falling within the scope of its activities. To facilitate such



Plan B organization



Plan C organization

participation, the basic unit should be the local chapter confined to the smallest practicable geographic or political area. The basic unit, therefore, could be the county. For greater effectiveness in dealing with civic and professional problems extending beyond the community, these chapters should be combined to form a state society. The state societies should in turn be united to form a national organization. The ideals and opinions of the individual engineers would be the basis of pronouncements by the society which then might be recognized by the public as the voice of the engineering profession.

Attaining Organization. Such an Engineering Profession Society if newly organized, would have a long hard struggle to acquire a membership sufficiently large to claim to be speaking for the entire engineering profession. It therefore would seem more expeditious to select and support some one existing society which was organized to accomplish the purposes of an Engineering Profession Society and which exhibits characteristics of steadily growing strength and influence. It is to be noted that this plan requires action by individual engineers rather than by organizations of engineers.

Membership. The membership of the Engineering Profession Society would be comprised entirely of individual engineers and there would need to be only one grade of membership. As 46 states have engineering registration laws, a requirement for membership well might be legal recognition by the state as being qualified to practice the profession of engineering.

PLAN C. FEDERATED ENGINEERING SOCIETIES

This plan proposes federation of existing engineering societies to form the Federated Engineering Societies. Federation would provide a single control for consideration and action on all technical and professional matters of interest to engineers.

Organization Required. The existing societies would have to find some basis for acting in a federation so that the constructive efforts of all could be applied to any problem considered.

The pattern for unifying existing engineering organizations is being developed in numerous local council and affiliation plans. Their stable and continued growth may indicate that the Federated Engineering Societies could meet the needs of engineers.

Attaining Organization. Federation of the existing engineering societies should create a strong Federated Engineering Society because their combined membership includes the majority of engineers and also because their combined activities include practically every activity that might add to the development of the engineering profession in its broadest scope.

In order to attain federation without delay and as smoothly as possible, the major national technical societies should take the lead with a positive approach toward unification and take the action required to supplement the small steps made already in the right direction.

For each society, the creation of an over-all organization for matters that are of common concern to all engineers is merely a pooling of efforts to improve the results. Engineers' Council for Professional Development seems to show that this idea has possibilities.

The steps that each society could take to facilitate federation are:

1. Expand this idea of joint action, on both a national and a local basis, by appointment of joint committees to work out specific solutions for the several specific problems of common interest to two or more of the present national organizations, such as licensing and professional recognition, or the matter of competition or overlap in technical programs.

2. Publish a general interest magazine to go to all individual members of all co-operating societies, both national and local. This magazine would publish top-notch articles now often limited in circulation to one society, plans and suggestions for local activities, an interchange of practical ideas, and reviews of technical advances based on papers in the technical societies.

3. Carry into engineering organizations the type of investigation which led to the Wickenden report for engineering education. The same improvements and the softened department border lines that have followed in college viewpoints are being sought in this new field, and there is a large amount o spade work involved in continuing this program.

4. Aim at an ultimate organization of the American Medical Association type, with its technical sections and local affiliations modified for our particular needs, realizing that this goal was not for them, and would not be for us, a single stroke achievement.

PLAN D. AMERICAN SOCIETY OF ENGINEERS; A SINGLE SOCIETY WITH INDIVIDUAL MEMBERSHIP FOR ALL AMERICAN ENGINEERS

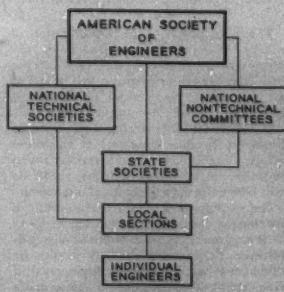
This plan proposes the setting up of a new American Society of Engineers into which would be incorporated many of the existing engineering societies.

Organization Required. Local sections and state societies would be the basic units in such a national organization. An individual who joined a local and state society would be eligible for individual membership in the American Society of Engineers and for membership in the national technical societies which would become subsidiaries of the American Society of Engineers. All activities other than technical would be carried on by state and national committees of the general society, each functioning in a special field of interest. All technical activities would be carried on by the national technical societies which would retain their present principle function, but drop all those activities related to the professional field.

The national technical societies would coordinate any sectional activities related to their technical field while the national professional committees would serve as the co-ordinating agency on problems of a professional nature and would serve as the spokesman for all engineers on national matters.

Local Sections. To meet individual needs, the basic organization would be built on local sections such as the Chicago Engineering Society or the New York Engineering Society. In more sparsely settled territories the local section might cover several counties instead of a single city.

The local sections would provide a general service to co-ordinate meeting dates, provide meeting quarters, and sponsor general meetings on the broader phases of engineering. The local sections also might have committees subsidiary to state com-



Plan D organization

mittees on legislation, civic activities, education, and other matters. These would cooperate with other local groups.

The handling of local section meetings on specialized technical subjects would be exactly the same as at present, except that branches of the local section would be formed to fill the needs of each locality. Thus a local section might have groups on steam generation, machine tools, chemical processes, industrial power, communication, aeronautics, dam construction, rivers and harbors, and electric power generation instead of having these subjects under the national societies as is the present practice. These groups would be co-ordinated, however, with the national technical societies. The responsibilities of the individuals would not be changed materially.

State Society or Regional Organization. A state society to be known as the Pennsylvania Society of Engineers, for example, would represent all those in the area on statewide general interest problems. In some instances, a regional organization might substitute for more than one state society. The state society would maintain mailing lists, process all applications for membership, maintain contact with student branches and the other professions within the state, and deal with all state legislation affecting the profession.

Student Branches. Student branches of the American Society of Engineers would be formed in all engineering colleges instead of branches of each specialized society. Co-ordination with the specialized technical societies would be accomplished through committee contacts. Separate student committees representing the specialized fields would conduct technical meetings. The number of students and the variety of the curriculum would determine what meetings would be held and the size of the organization for conducting them.

National Society. The American Society of Engineers through its top board of direction would act only on subjects of general national importance through committees shown in the organization diagram. Each state or regional society might be represented through a single representative on a board of trustees. The present national technical societies, practically intact, would be made a part of the American Society of Engineers. They would drop direct action on general subjects affecting all branches but each would continue to conduct its own conventions and standardizing activities and be co-ordinated with the technical groups under the local societies, furnishing papers, sponsoring prize awards for papers, and arranging for delegates to attend the various national conventions.

Membership Qualifications. To co-ordinate the various grades of membership of the present specialized technical societies, it is proposed that the basic voting grade of membership be available not only to registered professional engineers, but also to others having equivalent qualifications. The states registration requirements, while varying somewhat, are on nearly the same level and are being made more uniform.

A lower grade of voting membership would be equivalent to "engineer in training." This now has become a legally recognized status in some states, and is being adopted rapidly in others.

Nonvoting grades of membership, for which the qualification requirements would be lower, would include student members, affiliates, and local members. These would not be eligible to hold office in any of the state or national society activities.

Only a small number of persons might be eligible for a higher qualification such as honorary member or fellow. This grading would be administered on a state level for purposes of co-ordination.

Fifth Progress Report on AIEE Aeronautical Standards

Standardization work concerning aeronautical electric equipment still is being carried on under the direction of the AIEE air transportation committee. This report, which follows the fourth progress report (*EE, Jan '46, p 36*), brings up to date the status of the various projects.

AIRCRAFT ELECTRICAL SYSTEMS SUBCOMMITTEE

Under the chairmanship of R. H. Kaufmann (M '41) preliminary data concerning about half of the sections in the proposed report on aircraft electrical systems have been accumulated, and it is planned to compile these data in draft form for circulation and review at an early date rather than wait for information covering all of the sections to be accumulated. Some of the contributions to this report have been held up due to shifting of personnel in industry. This project is considered very worth-while by other interested bodies as well as by the air transportation committee and every effort is being made to obtain the necessary data for completion. Full co-operation is being give by Aeronautical Radio, Inc., a company which has done considerable work of this type. The AIEE report will be an informative type of report giving pertinent application and performance data, description of aircraft electrical systems, and so forth. Anyone having any data along these lines is urged to get in touch with R. H. Kaufmann, General Electric Company, Schenectady, N. Y.

AIRCRAFT ELECTRIC ROTATING MACHINERY SUBCOMMITTEE

A test code for d-c aircraft motors is in process of preparation and the third meeting of the subcommittee was held on January 22, 1946. Editorial work now is being undertaken to correlate the various sections of the proposed test code so that it will form a comprehensive composite unit. It is expected that the proposed test code will be ready for submission at the June meeting. M. L. Schmidt (M '43) is chairman.

AIRCRAFT ELECTRICAL CONTROL AND PROTECTIVE DEVICES SUBCOMMITTEE

The membership of this subcommittee (R. A. Millermaster (M '34) chairman) has been particularly upset due to industrial reconversion. Its work is being co-ordinated with that of the electrical systems subcommittee and also with the cable subcommittee. The work on control and protective devices will be crystallized when the other groups have advanced further.

AIRCRAFT WIRE AND CABLE SUBCOMMITTEE

Considerable progress has been made by this group, under the chairmanship of W. S. Hay, with excellent co-operation from various manufacturer and user interests. J. A. Scott (M '34) and B. W. Jones (M '43) are preparing a paper, "Short Time Current Ratings for Aircraft Wire and Cable," for presentation before the Institute. This paper will give the results of a series of tests on AN-16 and AN-8 insulated aircraft cables to determine their permissible short time current capacity and will include tentative recommendations for short time current carrying capacity for aircraft cables, sizes AN-22 to AN-00.

AIRCRAFT CARBON BRUSH SUBCOMMITTEE

Under the chairmanship of V. P. Hessler (F '43) this group is working actively on the preparation of a report on "Proposed Test Code for Aircraft Carbon Brushes." The subcommittee held its first meeting on January 24, 1946.

REPORT ON AIRCRAFT D-C APPARATUS VOLTAGE RATINGS (AIEE STANDARD 700)

This proposed Standard has been out now for almost a year and the air transportation committee plans to circularize the aircraft industry and military services for comments so that action can be taken soon toward the completion of a regular Standard.

ELECTRIC EQUIPMENT SAFETY SUBCOMMITTEE

A new subcommittee of the air transportation committee is to be formed to review available operating and test data which point to the type of electric equipment, methods of installation, and methods of operation which provide maximum safety in the performance of aircraft electric equipment, and to report concerning the desirability of committee action on this subject.

NASC—STANDARD METHOD OF ELECTRICAL LOAD ANALYSIS FOR AIRCRAFT

With K. R. Smythe (M '44) as chairman, certain d-c graph and chart forms have

been prepared by the project committee and submitted for forwarding to the Aeronautical Board. These are intended for use in the preparation of an AN specification, of which they would form a part, outlining a standard method of making a d-c electrical load analysis for military and naval aircraft. Some work also has been done concerning an a-c electrical load analysis. This activity has been disrupted somewhat since the termination of the war due to changes in personnel but it is expected that it soon will be carried forward to completion.

SAE COMMITTEE A-2, AIRCRAFT ELECTRIC EQUIPMENT

Under the chairmanship of C. C. Shangraw the work of this group is continuing along the same general plan as set up and an earnest hope has been expressed that the AIEE will continue with its work and bring forth reports and Standards concerning aircraft electric equipment at an early date.

SECTION

Gas Turbine Discussed Before Panhandle Section

Utilization of the many potential advantages offered by the gas turbine as a prime mover soon may be a realization according to an address before a recent meeting of the AIEE Panhandle Section in Amarillo, Tex. The speaker was John R. Carlson, an engineer with the Westinghouse Electric Corporation.

Mr. Carlson pointed out that the chief advantages of the gas turbine lie in its simplicity of design and operation, its compactness and relatively light weight. He predicted that, with the perfection of a reversible-pitch propeller to facilitate moving a ship either backward or forward, this prime mover next may be used to power ocean liners. Other uses might include its installation in locomotives; as auxiliary use on airplanes to provide lights, regulate wing flaps, and operate the landing gear; as central stations for provision of power for electric current; and as standby turbines to provide added power for heavily loaded distribution lines during busiest hours.

Any widespread use of the gas turbine as a central station power plant, however, depends upon economical operation. This factor was a detriment to progress for some time but war-stimulated research has resulted in the development of more durable metals which has made it possible to build up considerably more pressure within the turbine and, consequently, to concentrate more power into a smaller space. This trend leads to decreased original cost per turbine because of the fewer materials required for its manufacture as well as to reduced operating cost through better utilization of fuel.

ABSTRACTS

TECHNICAL PAPERS previewed in this section will be presented at the AIEE North Eastern District meeting, Buffalo, N. Y., April 24–26, 1946 and will be distributed in advance pamphlet form as soon as they become available. Copies may be obtained by mail from the AIEE order department, 33 West 39th Street, New York 18, N. Y., at prices indicated with the abstract; or at five cents less per copy if purchased at AIEE headquarters or at the meeting registration desk.

Mail orders will be filled AS PAMPHLETS BECOME AVAILABLE

Air Transportation

46-85-ACO—Electric Equipment for Cornell Variable-Density Wind Tunnel; *C. C. Clymer* (*A '42*), *M. A. deFerranti* (*M'43*). *25 cents.* Spectacular advances in airplane design during the past decade have created an increasing demand for additional testing facilities with which to obtain those data essential to successful design. To answer partially this demand and to facilitate more basic aerodynamic research on the subject of compressibility effects experienced in high-speed flight, several new wind tunnels were constructed during this same period. These tunnels vary widely in size and in requirements for air density and air speed in the tunnel working section. Correspondingly, the horsepower output requirements for their main fan-drive motors vary widely. But in all cases close speed regulation at preselected speed values over a wide range is essential to good test results. Most modern tunnels also incorporate suitable electric equipment for the operation of powered models and for the calibration of motors used in these models. This paper describes the Cornell variable-density wind tunnel from the viewpoint of electrical engineers and discusses principles governing the selection of electric equipment for wind tunnels.

46-86—Electric Equipment Required in the Modern Six-Component Wind-Tunnel Balance System; *H. O. Cox* (*A '35*). *20 cents.* This paper describes how the electric equipment was built into a compact mechanical assemblage and points out a few of the unique problems that had to be handled in order that the balance systems could be installed in the variable-density wind tunnels at the Cornell Aeronautical Laboratory and the Southern California Co-operative Wind Tunnel. The primary elements of the balance system, the electric drive required for each, and the control system used for automatic following of the wind-shielding and image system all are described in good detail.

46-87—Radiotelemetering for Testing Aircraft in Flight; *C. L. Frederick* (*M '45*). *30 cents.* A brief resume is given of the factors which necessitated the development of thoroughly practicable and reliable telemetering equipment for dynamic testing of high-speed aircraft in flight. An outline of a radiotelemetering system is presented which was developed under contract and accepted as suitable for structural flight testing by the United States Navy Bureau of Aeronautics in April 1945. Emphasis is placed on the electric system and circuits used which are of most interest to Institute members. These include the stabilized amplitude-modulated subcarrier oscillators, the frequency-modulated transmitter, the automatic-frequency-controlled frequency-modulation receiver, the heterodyne analyzer, and the mobile receiving station.

46-89—Hit Indicator Equipment for Gunnery Training with Frangible Bullets; *K. E. Burnham. 20 cents.* This paper deals with the development of equipment used to indicate and record the hits of frangible bullets on the surface of an armored pursuit aircraft. The aircraft, when modified and equipped, was used for training bomber gun crews in simulated combat aerial gunnery. The armor plate had to withstand the impact of the lead and plastic 30-caliber bullet. It was necessary to modify and use existing electronic equipment to record and indicate the hits on the aircraft surface. Later development work brought out a completely new indicating system custom-built to do the job.

Basic Sciences

46-84—Geometric Mean Distances for Rectangular Conductors; *H. B. Dwight* (*F'26*). *15 cents.* The geometric-mean-distance method of computing reactance is used a great deal with groups of round conductors. It would be useful also with rectangular conductors if values of geometric mean distance for such conductors were obtainable more readily. In this paper, curves for this quantity for rectangular conductors are given in such form that values can be determined conveniently with good accuracy for practical cases. Geometric mean distances can be used for computing the reactance of two rectangular bars forming a return circuit, no matter how close together the bars may be. The method is applicable also for 3-phase circuits and for cases where several conductors are in parallel. Two numerical examples are computed in detail.

Electronics

46-91—High Voltage Ignitron Rectifiers and Inverters for Railroad Service; *J. L. Boyer* (*A '43*), *C. G. Hagensick* (*A '44*). *30 cents.* This paper describes a new design of pumped ignitron type mercury-arc rectifier which has been developed for power conversion in the 3,000- to 4,000-volt range. These ignitrons were designed with emphasis on the heavy overload requirements of railroad service, which is the major application for this voltage class. The characteristics of power rectifier and inverter circuits are included to aid in determining the over-all performance. The design and test of two types of high voltage pumped ignitrons are described. The improved design for rectifier or inverter operation was obtained as a result of these tests.

Industrial Control

46-88-ACO—Application of the Electronic Oscillator to Measurement and Control; *P. M. Hackett. 20 cents.* This paper presents an electronic method to determine solution purity in a manner analogous to conductivity. No electrodes need contact the solution, however, and polarization and contamination effects are eliminated. Various other applications of radio frequency technique to industrial control problems also are presented and briefly summarized. A simple electronic circuit is given which will allow automatic power control from any industrial function that produces, or can be made to produce, a motion of matter. Control may be realized from almost any movement without contacting it or impeding its free motion. Examples of such motion are: movement of materials in level control applications, movement of mercury in a standard thermometer, mercury or other liquids in manometers. Mechanical motions, such as those of instrument pointers and expansion or stress movements, also may be detected, measured, and controlled within microscopic limits.

Industrial Power Applications

46-92-ACO—A Hot-Strip-Mill Flying-Shear Control Providing an Electric Tie Between Mill and Shear; *J. E. Sowers (M '43), V. A. Leitzke (A '41). 15 cents.* Increased production in the steel mill industry has placed more rigid requirements on all equipment. Satisfactory flying-shear performance requires a control which is flexible and accurate. Formerly controlled mechanically, the flying shear now has been successfully operated with an electric control system. The control utilizes a Ward Leonard system regulated by an amplidyne. A "coarse" speed control brings the "fine" speed control, which contains an electronic amplifier, into range, thus combining the flexibility of the amplidyne with the extreme sensitivity of the electronic control.

Land Transportation

46-90—Modern Double-Reduction Traction Motor; *Lanier Greer (M '42). 15 cents.* Incorporated in the modern double-reduction motor and gear unit are many new design features which have made it an outstanding motor for the past five years. Oil lubrication is provided for all gearing and bearings in the oiltight double-reduction gear unit. Special design constants, which have been developed as a result of many years of experience with high-speed motors are used. Self-ventilation is successful on a high-speed motor and simplifies locomotive design. Specially insulated field coils provide for good heat transfer from the coils to steel and air. A small motor with a high-speed armature results in low copper loss and high efficiency at high tractive effort. A steep speed curve with a large amount of field shunting makes it possible to use all motors connected permanently in parallel. The motor is small, compact, and lightweight, which has made possible its use on a wide range of locomotives.

Power Generation

46-100—Control of Frequency and Tie-Line Loads on the Niagara–Hudson System and Interconnected Systems; *B. S. Rice (A '44). 20 cents.* This paper covers equipment and methods used on the Niagara–Hudson system for the control of frequency and tie-line loads. A few operating problems are discussed together with planned extensions of these controls which will supplement and expand the present control system.

Power Transmission and Distribution

46-93-ACO—Incremental Transmission-Line Losses; *W. D. Wilder (A '46). 15 cents.* This paper will deal with a slide rule that has been developed to recognize incremental transmission losses as a supplement to incremental plant loading data. It is believed that results obtained are within 10 per cent of the true values, as results have been checked against a-c calculating board studies and fall within the foregoing limits. This slide rule has been so designed that incremental receiving end cost may be read directly, provided incremental production cost and initial transmission-line loadings are known.

46-99-ACO—A 1,000-Kva Mobile Substation and Its Service Record; *M. W. Bardwell (M '41). 15 cents.* This paper describes the mobile substation which was designed to carry 1,000-kva primary and secondary load, with a tertiary winding capacity of 350 kva. The transformer primary voltages selected conform to the voltages of our low-voltage transmission systems. They are the 44, 33, 22, 13.2, and 11-kv systems from which by far the greater number of our smaller stations are supplied. Adequate transformer taps were provided to cover the operating range of voltages of each system. Primary 44- and 33-kv connections are Y, 22-kv connections optional Y or delta, and 13.2- and 11-kv delta. The secondary connections are for 2,300, 4,600-volt delta or 4,000-volt Y. The tertiary windings are arranged for 230- or 460-volt delta.

Final Paper Abstracted for South West Meeting

The following abstract of a paper appearing on the technical program of the AIEE South West District meeting in San Antonio, Tex., April 16–18, 1946, was the only one not included in the list of abstracts published in the March issue of *Electrical Engineering*, page 130.

46-82-ACO—Some Problems of Distribution Engineering; *R. M. Walker (A '39). 15 cents.* Rate reductions and increased taxes make it necessary to reduce system investment and operating costs. The distribution system offers the engineer an opportunity to meet these requirements. Standardization of four-wire Y distribution and joint use with communication lines, reduces investment and eliminates wire crossing conflicts. Simplification of rate schedules helps to simplify a distribution system. One service of not more than four wires should meet the requirements of any customer. Serving loads of more than 200 kw from the subtransmission circuit relieves the distribution substation and distribution feeders. The voltage at the customer's service point can be improved without undue investment by the application of regulators and capacitors. Package-type unit substations of 500-kva and 750-kva capacity, with five per cent plus and minus tap-changing, and with suitable switchgear below 50,000 kva, should be available for use in rural areas or where the interrupting capacity is low. Fault protection by the use of co-ordinated fusing and relays will reduce outages of distribution lines. Periodic field checking of all distribution transformer loading is necessary to assure economic installations, as well as to prevent overloading of apparatus.

PERSONAL • • • •

A. H. Wing, Jr. (A '34, M '41) formerly electronics lecturer, Graduate School of Engineering, Harvard University, Cambridge, Mass., has been appointed associate professor of electrical engineering, Northwestern University Technological Institute, Evanston, Ill. Doctor Wing holds the degrees of bachelor of arts, bachelor of science, electrical engineer, and doctor of philosophy from Columbia University. He was associated with the General Electric Company from 1929 to 1932 at Schenectady, N. Y., and West Lynn, Mass., and in 1932 was made instructor in electrical engineering in the College of the City of New York. He joined the Harvard faculty in 1942, and has been on the staffs of the pre-radar school and the radio research laboratory. **R. R. Buss** (A '40) formerly research associate, Radio Research Laboratory, Harvard University, Cambridge, Mass., has been appointed assistant professor of electrical engineering, Northwestern Technological Institute. Doctor Buss was graduated from San Jose State College with the degree of bachelor of arts in 1935 and holds the degrees of electrical engineer and doctor of philosophy from Stanford University. Before becoming a member of the Harvard faculty in 1943 he was associated with the firms of Heintz and Kaufman, Ltd., San Francisco, Calif., and the Litton Engineering Laboratories, Redwood City, Calif. **J. A. M. Lyon** (A '38) until recently on active duty as a lieutenant in the United States Naval Reserve, has been appointed assistant professor of electrical engineering, North-

western Technological Institute. Doctor Lyon holds the degrees of bachelor of science, master of science, and doctor of philosophy from the University of Michigan. After brief periods with the Pittsburgh (Pa.) Reflector Company, the Metropolitan Edison Company, Reading, Pa., and the Utility Management Corporation, Reading, he joined the staff of Johns Hopkins University as instructor in electrical engineering in 1938. Before starting his naval service in 1943 he was assistant engineer with Ebasco Services, New York, N. Y.

G. L. Weller (M '26, F '31) formerly equipment and buildings engineer, Chesapeake and Potomac Telephone Company, Washington, D. C., has been made assistant chief engineer. Mr. Weller, who had been equipment and buildings engineer since 1929, joined the telephone company in Baltimore, Md., in 1901. His assignments have included application of standards, installation of pioneer public address systems, inventory, and appraisal work. He was appointed maintenance supervisor in 1927. He has been active in AIEE Washington Section affairs. **H. P. Howard, Jr.** (M '44) formerly plant extensions engineer of the Chesapeake and Potomac company, has been appointed equipment and buildings engineer. Mr. Howard received his bachelor of science degree from the United States Naval Academy in 1924. He has been with the Chesapeake company since 1935 as general traffic engineer, general traffic supervisor, and plant extensions engineer, which he was appointed in 1942. **E. R. Greenleaf** (A '39, M '45) transmission and outside plant engineer, Chesapeake and Potomac company, has been appointed plant extensions engineer. Mr. Greenleaf, who has been with the company since 1929, has been general traffic engineer and general traffic supervisor. He was made transmission and outside plant engineer in 1935.

H. H. Scott (A '32, M '38) formerly engineer in charge of acoustics, General Radio Company, Cambridge, Mass., is now president of the newly formed Technology Instrument Corporation, Waltham, Mass. Mr. Scott was graduated from Massachusetts Institute of Technology in 1930, received the degree of master of science in 1931, and in the latter year joined the General Radio Company as executive engineer. He has been responsible for the development of sound and vibration measuring equipment, frequency modulation and broadcast station monitoring equipment, and other radio frequency and audio measuring instruments. He has twice received the product design award of *Electrical Manufacturing* and is the author of a number of technical papers. **L. E. Packard** (A '40, M '41) formerly manager of the Chicago, Ill., office of the General Radio Company, is treasurer and in charge of sales in the new company. Mr. Packard, a 1935 graduate of Massachusetts Institute of Technology, joined the General Radio Company that same year. Since 1939 he had been manager first of the company's New York, N. Y., office and then of its Chicago office.

M. L. Manning (A '36, M '42) formerly assistant chief engineer, Kuhlman Electric Company, Bay City, Mich., has been appointed chief engineer. Mr. Manning holds the degrees of bachelor of science from South Dakota State College (1927) and master of science from the University of Pittsburgh (1932). He first joined the Westinghouse Electric Corporation, East Pittsburgh, Pa., as design engineer in 1929 and, after a period as instructor in mathematics at Pennsylvania State College in 1931 and 1932 and at the University of Pittsburgh from 1932 to 1936, returned to the Westinghouse company in 1936. He was titled research engineer in 1937 and later was Westinghouse lecturer at the University of Pittsburgh. In 1942 he became associate professor of electrical engineering at the Illinois Institute of Technology and in 1943 was appointed associate professor of electrical engineering and director of the new high voltage research laboratory at Cornell University, Ithaca, N. Y. He joined the Kuhlman company in 1945. Mr. Manning is a member of the Society for the Promotion of Engineering Education, the American Mathematical Society, and Sigma Tau and has been active in AIEE Section affairs.

W. P. Schwabe (A '96, M '24) manager of the northern division, Connecticut Light and Power Company, Thompsonville, has retired. Mr. Schwabe commenced his career with the Rutherford, N. J., Electric Light Company, which eventually was absorbed by the Public Service Corporation of New Jersey, from 1893 to 1908. In those years he rose from cadet engineer to superintendent of the electric department and district agent. In 1908 he joined the Northern Connecticut Light and Power Company as general manager and in 1915 became vice-president and general manager. He was also president and general manager of the Thompsonville Water Company and the Stafford Springs Aqueduct Company. After the Northern Connecticut company was acquired by the Connecticut Light and Power Company he became northern division manager. Mr. Schwabe was active in the National Electric Light Association and in the AIEE Connecticut Section.

T. N. Lacy (M '24, F '43) formerly vice-president and general manager, Michigan Bell Telephone Company, Detroit, is now president of that company. Mr. Lacy entered the long lines department of the American Telephone and Telegraph Company, Philadelphia, Pa., in 1906 following his graduation from Lehigh University. He became line inspector in 1909 and in that capacity was transferred to New York in 1911. He was sent to Atlanta, Ga., as division plant engineer in 1912 and became division plant superintendent in 1919. As division plant superintendent he went to the Michigan Bell company in 1925 and later that year became chief engineer. He was appointed vice-president and general manager and elected to the board of directors in 1934.

F. W. Bush (A '36, M '43) formerly assistant to the manager, electrical department, Allis-Chalmers Manufacturing Company, Milwaukee, Wis., has been promoted to assistant manager. A graduate of the Georgia School of Technology with a bachelor of science degree in electrical engineering (1928), Mr. Bush has been associated with the company since 1928. He has been student engineer, assistant engineer in the transformer engineering department, engineer in charge of the high voltage laboratory, application engineer, and engineer in charge of transformer sales. In 1941 he became assistant to the manager of the electrical department.

H. N. Muller, Jr. (A '37, M '43) central station engineer, Westinghouse Electric Corporation, East Pittsburgh, Pa., has been promoted to the position of manager of graduate student training. Mr. Muller, who was graduated from Dartmouth College with a bachelor of arts degree in physics (1935), has been with the Westinghouse company since his graduation. Entering the graduate student training course, he was assigned first to the materials and process engineering department and later was transferred to the central station engineering department. He is a member of the AIEE committee on power generation, 1944–47.

E. H. Ginn (A '03) commercial vice-president, General Electric Company, Atlanta, Ga., has retired from that position but will remain in an advisory capacity with the company until July 1, 1946. Mr. Ginn, who was born in Worcester, Mass., was graduated from the Worcester Polytechnic Institute in 1900. He joined the General Electric Company in 1901 and for a time was in the railway engineering department in Atlanta. In 1912 he was district manager of the railway and light department. He was made district sales manager in 1915, district manager in 1922, and was appointed commercial vice-president in 1936.

R. P. Smith (M '43) formerly general farm sales manager, Westinghouse Electric Supply Company, New York, N. Y., has become manager of the Midwest district of the company with headquarters at St. Louis, Mo. Mr. Smith, who has been with the company since 1923, first worked as sales correspondent and order clerk in the Baltimore, Md., plant and the Richmond, Va., branch and as salesman for the Miami, Orlando, and Jacksonville, Fla., branches. He was Florida division manager from 1933 to 1939, and was district apparatus and supply sales manager until May 1944, at which time he became chief

of the electrical section of the War Production Board, Washington, D. C. In 1945 he returned to the Westinghouse company as farm sales manager.

Robert Paxton (A '26, M '40) formerly manager of the Philadelphia (Pa.) works of the General Electric Company, has been made manager of the company's Pittsfield, Mass., works. Mr. Paxton entered the employ of the company in 1923 in the switchboard department, Schenectady, N. Y., after his graduation from Rensselaer Polytechnic Institute. He was transferred to the oil circuit breaker division at Philadelphia and in 1929 was made managing engineer of the metal enclosed division. He was named managing engineer of the panel and equipment division in 1932 and assistant to the manager in 1940. In 1941 he became manager of the Philadelphia works.

A. L. Thurman (A '38, M '45) application engineer, General Electric Company, Schenectady, N. Y., since 1941, has been appointed chief electrical engineer, Aetna-Standard Engineering Company, Youngstown, Ohio. He holds from the Oklahoma Agricultural and Mechanical College a bachelor-of-science degree in electrical engineering (1936), bachelor-of-science degree in mechanical engineering (1937), and a master-of-science degree in electrical engineering (1937). Mr. Thurman was research assistant and part-time instructor at the Oklahoma college before going to the General Electric Company in 1937.

S. F. Butler (A '23) member of technical staff, Bell Telephone Laboratories, Inc., New York, N. Y., retired in 1945 after spending 45 years in the service of the company. A native of Marlboro, Mass., Mr. Butler went to work for the New England Telephone Company in the engineering department, Boston, Mass., in 1900. Subsequently, he was with the Western Electric Company at Hawthorne, Ill., and in 1919 went to the Bell Telephone Laboratories in New York. In 1921 he was placed in charge of the current development and trial installation group and later became switching equipment engineer.

H. S. Dusenbery (A '44) formerly supervisor, electrical production control, Moore Dry Dock Company, Oakland, Calif., has been appointed to the college of engineering, University of Santa Clara (Calif.) where he will conduct a number of courses in electrical engineering. Mr. Dusenbery, a graduate of the University of California with a bachelor-of-science degree in electrical engineering (1917), was associated at one time with the Pacific Gas and Electric Company, San Francisco, Calif. He is co-author of "Practical Marine Electricity."

D. B. Smith (A '35) director of research, Philco Corporation, Philadelphia, Pa., since 1941, has been appointed vice-president in charge of engineering. Mr. Smith, a native of Newton, N. J., received a bachelor-of-science degree from Massachusetts Institute of Technology (1933) and a master of science degree in electrical engineering (1934). In the latter year he joined the Philadelphia Storage Battery Company as a member of the engineering department. He has served as a patent engineer on radio, television, and other applications of electronics. He was appointed technical consultant to the vice-president in charge of engineering in 1938, and was promoted to director of research in 1941.

Paul MacGahan (A '02, F '42) recently retired development engineer, Westinghouse Electric Corporation, Newark, N. J., now is engaged in private consulting practice in Woodstock, N. Y. A graduate of Columbia University (1896) with a degree in electrical engineering, Mr. MacGahan became associated with the Westinghouse company in 1897. He has served on the following AIEE committees: protective devices, 1918–20; instruments and measurements, 1922–24, 1930–45; and technical program, 1931–33.

J. M. Cage (M '44) engineer in charge, electronic devices section, Allis-Chalmers Manufacturing Company, Milwaukee, Wis. has been appointed manager, industrial electronics division, Raytheon Manufacturing Company, Waltham, Mass. A graduate of Iowa State College, Mr. Cage first worked for the General Electric Company, Schenectady, N. Y., and before joining Allis-Chalmers Manufacturing Company in 1943 served as associate professor, department of electrical engineering, University of Colorado, Boulder, for four years.

E. H. Mittanck (A '28, M '40) engineer, Southwestern Bell Telephone Company, Dallas, Tex., and more recently lieutenant colonel, Army of the United States, has returned to the Southwestern Bell Telephone Company. A graduate of the Texas Agricultural and Mechanical College (1927) with a bachelor-of-science degree in electrical engineering, Colonel Mittanck joined the staff of the Southwestern Company in 1927.

C. M. Lynge (M '22) assistant works manager, General Electric Company, Bridgeport, Conn., was appointed manager there effective January 1, 1946. He will continue as assistant manager of manufacturing of the appliance and merchandise department at Bridgeport. Mr. Lynge has been associated with the General Electric Company since 1913 and has served successively as design engineer, in the cost and production department, and on motor manufacture in Pittsfield, Mass. He transferred to Bridgeport in 1920.

J. E. O'Brien (A '29, M '39) formerly major, United States Marine Corps Reserve, and chief of the experimental section, Marine Corps Equipment Board, Quantico, Va., has been appointed principal engineer of the newly created new development section of the Rural Electrification Administration. Following his graduation from the Catholic University of America in 1927, Mr. O'Brien remained at the university as assistant instructor, and assistant professor of electrical engineering. He joined the REA in 1940 and was head of the Special Problem Section, Technical Standards Division when he was called to active duty in 1942. He is a past chairman of the AIEE Washington Section.

W. E. Keith (A '25) formerly personnel staff assistant, New England Telephone and Telegraph Company, Boston, Mass., has been appointed general employment and training supervisor. Mr. Keith entered the Bell system as student engineer with the Bell Telephone Company of Pennsylvania, Philadelphia, in 1922 after his graduation from Worcester Polytechnic Institute. He was transferred to the New England company in 1923 and since has served as director of college relations, exchange rate engineer, general commercial training supervisor, and branch manager. He was appointed assistant to the vice-president in 1939 and personnel staff assistant in 1944.

A. D. Pettee (A '20, M '37) formerly technical superintendent, General Cable Corporation, Bayonne, N. J., has been appointed chief electrical engineer of the company. Mr. Pettee, who was born in Andover, Mass., in 1889, holds the degrees of bachelor of arts from Yale University and bachelor of science from Massachusetts Institute of Technology. His first position was assistant electrical engineer with the International Harvester Corporation, Chicago, Ill., in 1919. From 1921 to 1929 he was assistant distribution engineer with the New York (N. Y.) Edison Company. Since 1929 he has been with the General Cable Corporation as cable engineer, sales engineer, consulting engineer, and district sales engineer. He was appointed technical superintendent in 1943.

W. E. Beaty (A '11) electrical engineer, Cincinnati (Ohio) Gas and Electric Company, has retired. Mr. Beaty joined the Cincinnati company in 1901 as meter reader and repairman, became head of that department, and was transferred to the engineering department as assistant to the department head. In 1910 he was appointed assistant superintendent of electric distribution, and, when the Columbia Engineering and Management Corporation was formed in 1923, he was transferred to that corporation to take charge of electric transmission and distribution work. He rejoined the Cincinnati company in 1930 and since had been working on estimates and budget control for the electric distribution department.

F. E. Sanford (A '28, M '34) formerly superintendent of distribution engineering, Cincinnati (Ohio) Gas and Electric Company, has become Western editor for *Electrical World*. Mr. Sanford had been with the Cincinnati company since his graduation from the University of Cincinnati in 1922. He served as transmission engineer and distribution engineer, and recently had supervised construction layout, transformer operation, voltage control, right of way, load analysis, and system planning. He has served on Edison Electric Institute and AIEE committees and is the author of "Electric Distribution Fundamentals." He is a member of the Engineering Society of Cincinnati and a past president of the Technical Societies Council of Cincinnati.

C. S. Bowden (M '42) formerly supervising engineer, Ohio Public Service Company, Elyria, is now production manager and assistant to the vice-president in charge of operations. Mr. Bowden, who was graduated cum laude from the University of Colorado in 1923, has been with the Ohio company since 1925 and before that was associated with the Public Service Company of Colorado, Denver, and the City Light and Water Company, Amarillo, Tex. **M. A. Giles** (A '39) formerly service manager, distribution department, Ohio Public Service Company, Mansfield, has been placed in charge of the central engineering department at Elyria. Mr. Giles, a 1922 graduate of the University of Wisconsin, joined the company in 1926.

D. R. Edge (A' 44) formerly manager of the Central Electric Co-operative, Inc., Parkers Landing, Pa., has been appointed assistant rural lines sales manager for the Graybar Electric Company, Inc., Chicago, Ill. Since 1936 Mr. Edge has been active in Rural Electrification Administration work, managing the Union Rural Electric Co-operative, Marysville, Ohio, before he organized the Central Electric Co-operative. Previously Mr. Edge had been with the General Cable Corporation, New York, N. Y., for four years.

H. D. Larrabee (A '06) eastern division manager, Connecticut Light and Power Company, Willimantic, has retired. Mr. Larrabee was graduated from the Massachusetts Institute of Technology in 1902 and was employed by the General Electric Company and by utilities in Puerto Rico, Illinois, Indiana, and Vermont before 1919, in which year he went to Norwich as manager of the Eastern Connecticut Power Company. In 1929 he became eastern division operating superintendent of the Connecticut Light and Power Company which acquired the Eastern Connecticut company at that time.

J. K. Hodnette (A '25, F '42) formerly manager of engineering, engineering department, transformer division, Westinghouse Electric Corporation, Sharon, Pa., has been made manager of the transformer division. A 1922 graduate of the Alabama Polytechnic Institute, Mr. Hodnette has been with the Westinghouse corporation since his graduation. He was laboratory assistant at the East Pittsburgh, Pa., works until 1924. At that time he was transferred to Sharon. Mr. Hodnette was named a modern pioneer of industry in 1940 by the National Association of Manufacturers.

A. L. Jones (A '07, F '38) commercial vice-president, General Electric Company, Denver, Colo., has retired. Mr. Jones, who was born in Ballston, N. Y., was graduated from Cornell University in 1904 and that year started his career in the testing department of the General Electric Company. After some experience in the power mining engineering department, he was transferred to Denver as district engineer in 1909. He was appointed assistant district manager in 1926 and district manager in 1928. He had been commercial vice-president since 1936.

H. D. Moreland (A '35, M '41) formerly manager of X-ray engineering, Westinghouse Electric Corporation, Baltimore, Md., has been made manager of the company's X-ray division in Baltimore. Mr. Moreland, who holds the degrees of bachelor of science and master of science in electrical engineering from the Oregon State College, joined the Westinghouse company as an X-ray serviceman in Portland, Oreg., in 1933. He was transferred to San Francisco, Calif., as salesman in 1935 and returned to Portland as X-ray manager in 1938. From 1942 until he went to Baltimore in 1944, he was manager of X-ray products in East Pittsburgh, Pa.

W. A. Kelley (A '38) lieutenant colonel, Army Signal Corps, Lexington, Ky., recently was awarded the Legion of Merit. The citation states that Colonel Kelley who was commanding officer of the Stock Numbering Agency was responsible for classifying, cataloging, stock numbering, and code numbering all items of Signal Corps equipment and supplies. Prior to his active duty with the Army, Colonel Kelley served with the War Production Board, of which he organized seven divisions. During his Army service his book, "The Universal Catalog System," was published.

W. C. Wagner (A '06, F '41) formerly general superintendent, meter division, Philadelphia (Pa.) Electric Company and more recently a captain, United States Naval Reserve, has returned to his former position. Called to active duty as a lieutenant commander in 1941, he was commissioned captain in 1945. He served as research engineer, head of the research section, and head of the electricity section of the research and standards branch of the Bureau of Ships, Washington, D. C.

L. E. Williams (A '41) formerly assistant professor of electrical engineering, University of Pittsburgh, Pittsburgh, Pa., has been appointed assistant professor of electrical engineering at the University of Connecticut, Storrs, from which he was graduated in 1940. Professor Williams also was employed for a time by the Westinghouse Electric Corporation, East Pittsburgh, Pa. He is a member of Eta Kappa Nu and Sigma Tau.

H. B. McIntyre (M '38) formerly toll rate engineer, New England Telephone and Telegraph Company, Boston, Mass., has been appointed general rate engineer of the company. Mr. McIntyre was graduated from Colby College in 1920 and from Massachusetts Institute of Technology in 1922. He joined the company in 1924 as division commercial assistant, became rate engineer in 1929, and assistant exchange rate engineer in 1935. He has been toll rate engineer since 1941.

W. B. Clayton (M '40) commercial vice-president, General Electric Company, Dallas, Tex., adds responsibility for the company's territory of Denver, Colo., and its environs to his duties. **A. S. Moody** (A '09) commercial vice-president, General Electric Company, Portland, Oreg., assumes the additional responsibility of the territory from Butte, Mont., westward.

Clarence Arnott (A '27, M '43) formerly assistant superintendent, engineering division, electrical department, British Columbia Electric Railway Company, Ltd., Vancouver, Canada, is now assistant general superintendent of the company. Mr. Arnott was graduated from the University of British Columbia in 1929 and has been associated with the British Columbia Railway company as draftsman, assistant engineer, assistant valuation engineer, and since 1941 as assistant superintendent of the engineering division.

C. L. Richardson (M '44) major, Canadian Royal Corps of Signals, has been appointed inspector of Signals Division, Directorate of Signals and Engineering, Inspection Board of United Kingdom and Canada, with headquarters in Ottawa, Ontario. Major Richardson was chief radio engineer for the Canadian General Electric Company, Toronto, from 1924 to 1928 and afterwards was consultant for many sound and film companies. He was called to active duty as a captain in 1940.

F. W. Tatum (A '42, M '45) formerly engineer, American District Telegraph Company, New York, N. Y., has been appointed engineering supervisor. Mr. Tatum was graduated from Columbia University in 1935 and thereupon joined the plant department of the American District Telegraph Company. He entered the engineering department in 1936 and since 1944 has been in charge of the electronics training courses for company personnel.

I. A. Terry (A '27, F '37) formerly assistant to the vice-president, apparatus department, General Electric Company, Schenectady, N. Y., has transferred to the Fort Wayne (Ind.) Works of the company as works engineer. He was a member of the AIEE board of examiners, 1944–46.

W. M. McKie (A '41) formerly in the engineering department, Canadian General Electric Company, Limited, Peterborough, Ontario, and more recently retired as flight lieutenant, Royal Canadian Air Forces, has joined the switchgear section, central station division, apparatus department, Canadian General Electric Company.

C. F. Kettering (A '04, F '14) vice-president in charge of research, General Motors Corporation, Dayton, Ohio, received an honorary membership in the American Society of Civil Engineers at its recent annual meeting in New York, N. Y. Mr. Kettering won the Washington Award in 1936, and the John Fritz Medal in 1944.

R. H. Snyder (A '38) formerly of Cranford, N. J., has been appointed general sales manager of the Hertner Electric Company, Cleveland, Ohio, subsidiary of General Precision Equipment Corporation, New York, N. Y. Mr. Snyder was graduated from New York University in 1933 with a bachelor-of-science degree in electrical engineering.

H. L. Olesen (M '27) sales promotion manager, Weston Electrical Instrument Corporation, Newark, N. J., is now general sales manager. An electrical engineering graduate of the University of Illinois (1918), Mr. Olesen has been associated with the Weston company since 1931 and has been in charge of radio sales, assistant general sales manager, and sales promotion manager.

E. E. Hill (A '16) formerly associate manager, electric production department, Consolidated Edison Company of New York (N. Y.), Inc., has been appointed executive assistant to the executive vice-president. Mr. Hill entered the employ of the New York Edison Company in 1904 and filled all positions in the meter department from assistant meter tester to general foreman.

C. M. Veronda (A '43) until recently a member of the staff of the Naval Research Laboratory, Boston, Mass., is now assistant engineer, microwave section, Philips Laboratories, Inc., Irvington, N. Y. Mr. Veronda was graduated from the California Institute of Technology in 1942 and before entering the Navy was employed in the heating device engineering department of the General Electric Company, Bridgeport, Conn.

W. F. Wolfner II (A '41) formerly major in the Army Signal Corps, has been appointed director of audiovisual engineering, Jordanoff Electronics Corporation, New York, N. Y. Before the war Mr. Wolfner, a 1938 graduate of the University of Michigan, was associated with the Electronics Control Corporation, Detroit, Mich., and with Photoswitch, Inc., Cambridge, Mass.

C. J. Nevitt (A '33) formerly assistant superintendent, San Diego (Calif.) Gas and Electric Company, has been made superintendent. After his graduation from the University of California in 1931, Mr. Nevitt was associated with the San Joaquin Light and Power Company, Fresno, Calif. He moved to San Diego in 1932 and was employed in the city's water utility evaluation and engineering department. In 1936 he joined the San Diego company's engineering department, and in 1945 he was made assistant superintendent of the electric transmission and distribution department.

W. J. Mann, Jr. (M '43) formerly vice-president, Wolfe and Mann Manufacturing Company, Baltimore, Md., is now president of the company. Mr. Mann was graduated from the University of Virginia in 1910 and for eight years afterwards was associated with the Westinghouse Electric Corporation, East Pittsburgh, Pa. Following brief periods with Bartlett Hayward Company, Baltimore, and the Standard Electric and Elevator Company, Baltimore, he became vice-president of The Wolfe and Mann company in 1922.

W. H. Snowden (A '37) formerly major, United States Army, has returned to *Electrical West* as engineering editor. He was ordnance executive officer of the Third Infantry Division which was in action in Africa, Sicily, Italy, and France. He was awarded the Legion of Merit for activity in the Sicilian and Italian campaigns and later received an oak leaf cluster for outstanding work on the War Department general staff, to which he was attached in 1944 and 1945.

A. L. Kerrigan (A '30, M '39) formerly lieutenant colonel, United States Army, has returned to the Fitchburg (Mass.) Gas and Electric Company as general superintendent. Mr. Kerrigan, who was graduated from Massachusetts Institute of Technology in 1921, previously was associated with the New York (N. Y.) Edison Company, the Westinghouse Lamp Company, Bloomfield, N. J., and Charles H. Tenney and Company, Boston, Mass. He joined the Fitchburg company in 1936.

N. E. Wilson (A '38) formerly assistant professor of electrical engineering, Thayer School of Engineering, Dartmouth College, Hanover, N. H., has been appointed Westinghouse fellow at the Illinois Institute of Technology, Chicago, for the year 1945–46. The fellowship provides for a year of study in power systems engineering and work on the a-c network calculating board. A Cornell University graduate, Mr. Wilson was employed by the Westinghouse Electric Corporation after his graduation in 1937 and later was instructor at the University of Maine.

A. S. Glasgow (A '08) superintendent of the transmission and distribution department, San Diego (Calif.) Gas and Electric Company, has retired. Mr. Glasgow was born in Bellwood, Pa., in 1878, and was graduated from Pennsylvania State College in 1901. That same year he joined the General Electric Company and in 1903 was transferred to its San Francisco office, and the following year to Los Angeles, Calif. In 1916 he entered the employ of the San Diego Company as its first district agent at Oceanside, Calif. In 1928 he was transferred to San Diego.

J. E. Teckoe (M '29) manager of the Hydro-Electric Commission of Niagara Falls, Ontario, Canada, has retired. Mr. Teckoe was born in 1874 in Shrewsbury, England, and prior to his becoming manager of the Hydro-Electric Commission of Niagara in 1921 had been superintendent of the Hydro-Electric System of Tillsonbury, Ontario, from 1913 to 1921. Mr. Teckoe was electrician to the Town of Strathroy, Ontario, in 1906, and to the town of Powassan in 1909. In 1911 he became electrician and manager of the town of Ayr, Ontario.

R. V. Hartley (A '16, M '23) research consultant, research department, Bell Telephone Laboratories, Inc., New York, N. Y., was awarded the medal of honor of the Institute of Radio Engineers, New York, at its annual meeting January 24, 1946. **P. C. Goldmark** (M '45) chief television engineer, Columbia Broadcasting System, Inc., New York, was the recipient of the IRE Morris-Liebmann Memorial Prize.

OBITUARY

Irving Thompson Faucett (A '11, F '28) chief engineer, General Cable Corporation, New York, N. Y., died January 16, 1946. Mr. Faucett was born May 12, 1885, in Stamford, Conn., and studied at Cooper Union Institute. He commenced his electrical career in 1905, gaining experience in several firms in Stamford and New York, including the Western Electric Company, the Westinghouse Electric Corporation, and the Brooklyn Edison Company. In 1911 he joined the Safety Insulated Wire and Cable Corporation as assistant foreman of tests and in 1913 became foreman of tests. He advanced to standard practice engineer in 1920 and chief engineer in 1923. In 1928 he became superintendent and later manager of the company's Bayonne, N. J., plant. He became vice-president in 1929 and then director of high-voltage engineering for the General Cable Corporation of which the Safety Cable Company had become a division. He was named consulting engineer in

1933, product sales manager in 1938, and chief engineer in 1940. Mr. Faucett was chairman of several committees of the Insulated Power Cable Engineers Association and was coauthor of a number of articles.

John Napier Wallace (M '14; F '20) managing director, Equipment, Ltd., Wellington, N. Z., died November 4, 1945. Mr. Wallace was born September 2, 1883, in London, England, and was graduated from the Chicago Manual Training School in 1899. The year of his graduation he entered the employ of the Western Electric Company, Chicago, Ill. During 1903 he served in the central office and the equipment engineering department in New York and in 1904 returned to Chicago. In 1905 he was placed in charge of the experimental and circuit laboratories. He joined the Vote Berger Company, La Crosse, Wis., as assistant chief engineer in 1907 and a year later was appointed chief engineer and superintendent. Returning to the Western Electric Company in 1910, he traveled to Berlin, Germany; Antwerp, Belgium; and Australia and New Zealand in connection with the construction of automatic telephone plants in those countries. After 1914 he remained in New Zealand at first with the Western Electric Company and later with Equipment, Ltd. From 1931 to 1933 Mr. Wallace served on the Wellington City Council. He was a member of the New Zealand Institute of Engineers and had a number of patents issued in his name.

Charles Porterfield Kahler (A '10, M '23) chief electrical engineer, Union Pacific Railroad Company, Omaha, Nebr., died February 25, 1946. Born November 25, 1880, in Baltimore, Md., Mr. Kahler received the degree of civil engineer from the University of Notre Dame. He also studied at Baltimore City College, Maryland Institute, and Alexander Hamilton Institute. After his graduation in 1903 he remained at Notre Dame University, South Bend, Ind., as instructor and assistant professor. From 1904 to 1906 he was assistant engineer for the Chicago and St. Louis Railway, Cleveland, Ohio. In 1906 he entered the Union Pacific system as assistant to the chief engineer of the Oregon Short Line Railroad, Salt Lake City, Utah, and in 1912 was named electrical engineer. About 1932 he was transferred to Omaha as system electrical engineer, and in 1939 he was appointed chief electrical engineer. Mr. Kahler was a former chairman of the AIEE Nebraska Section and had served on the AIEE committees on membership and land transportation. He also was a member of the American Society of Civil Engineers and the Association of Electric Railway Engineers and the author of several papers.

Wilbur Cover Thomas (A '24, M '39) toll plant extension engineer, Southern California Telephone Company, Los Angeles, died February 27, 1946. Mr. Thomas was born May 8, 1897, in Georgetown, Colo., studied at Princeton University and received the degree of bachelor of science in electrical engineering from Throop College of Technology in 1918. Mr. Thomas served in World War I as a lieutenant in the Signal Corps and afterwards was overseas representative in China for the Standard Oil Company. Returning to the United States in 1921, he joined the Southern California Company and was engaged in exchange transmission design work until 1928. In that year he was placed in charge of toll transmission design work. He was a member of Tau Beta Pi and the Telephone Pioneers of America.

Leslie Elson Ross (A '29) general superintendent and vice-president, Niagara Falls (N. Y.) Power Company, died December 22, 1945. Born January 28, 1885, Mr. Ross had been associated with the company and its predecessors for about 45 years. He commenced his career as a lineman's helper for the Hydraulic Power and Manufacturing Company. He was made operating superintendent by the Niagara Falls Company in 1924 and general superintendent in 1929. He was given the additional duties of general superintendent of generation and transmission of the Buffalo, Niagara, and Eastern Power Corporation in 1934. In 1941 he was appointed vice-president.

MEMBERSHIP . . .

Recommended for Transfer

The board of examiners, at its meeting of March 21, 1946, recommended the following members for transfer to the grade of membership indicated. Any objections to these transfers should be filed at once with the secretary of the Institute.

To Grade of Fellow

Bush, R. M., major, Corps of Engineers, U. S. Army, Atlanta, Ga.

Butler, J. W., sponsor engr., cent. station engg. div., General Elec. Co., Schenectady, N. Y.

Chute, G. M., application engr., General Elec. Co., Detroit, Mich.

Dean, S. M., chief engr. of system, Detroit Edison Co., Detroit, Mich.

Foltz, L. S., prof. of elec. engg., Michigan State College, E. Lansing, Mich.

Gault, J. S., assoc. prof. of elec. engg., Univ. of Michigan, Ann Arbor, Mich.

Knickerbocker, W. G., supt. of meters, Detroit Edison Co., Detroit, Mich.

Outline, J. E., systems dev. engr., Automatic Elec. Co., Chicago, Ill.

8 to grade of Fellow

To Grade of Member

Alger, C. S., assoc. engr., Puget Sound Power & Light Co., Seattle, Wash.

Balfour, M. W., assoc. engr., Consumers Power Co., Jackson, Mich.

Blackett, H. W., plant elec. engr., Canadian Westinghouse Co. Ltd., Hamilton, Ont., Can.

Bowlus, O. E., project engr., Chrysler Corp., Detroit, Mich.

Bradley, J. J., asst. supt. of elec. installations, General Elec. Co., Philadelphia, Pa.

Buck, D. H., lieutenant (jg), U. S. Navy Dept., Bureau of Aeronautics, Washington, D. C.

Cain, B. M., engg. asst., General Elec. Co., Lynn, Mass.

Carr, B. P., assoc. engr., Consumers Power Co., Jackson, Mich.

Emery, W. L., radio engr., dept. of elec. engg., Iowa State College, Ames, Iowa

Ennis, B. J., elec. engr., Burns & McDonnell Engg. Co., Kansas City, Mo.

Erickson, W. H., asst. prof., elec. engg. dept., Cornell Univ., Ithaca, N. Y.

Fleming, W. R., maint. engr., electrical, Chicago District Elec. Generating Corp., Chicago, Ill.

Foley, R. J., supt., elec. distribution, Public Service Board, San Antonio, Tex.

Goodell, F. H., ind. heating engr., Trumbull Elec. Mfg. Co., Norwood, Ohio

Grundel, W. W., engg. representative, Elec. Storage Battery Co., San Francisco, Calif.

Haupt, L. M., prof. of elec. engg., A. & M. College of Texas, College Station, Tex.

Hess, H. M., assoc. prof. of elec. engg., Wayne University, Detroit, Mich.

Hurlbut, H. C., sr. elec. engr., Supervisor of Shipbuilding, USN, Seattle, Wash.

Johnson, E. M., engr., General Elec. Co., Seattle, Wash.

Kinsey, J. F., distribution engr., Public Service Elec. & Gas Co., Hackensack, N. J.

Litman, S., assoc. prof. of elec. engg., Univ. of South Carolina, Columbia, S. C.

Matthews, A. H., chief distribution engr., Ohio Power Co., Canton, Ohio

Mayer, L. F., electrical design engr., United Engineers & Constructors, Philadelphia, Pa.

McCandless, W. H., elec. engr., AAF Technical Service Command, Wright Field, Dayton, Ohio

McCart, S. O., dist. meter & instrument specialist, General Elec. Co., Cleveland, Ohio

McCloska, F. W., elec. engr., Sargent & Lundy, Chicago, Ill.

McIntire, R. L., supt., Shawnee Div., Oklahoma Gas & Elec. Co., Shawnee, Okla.

McNair, I. M., analysis engr., system planning dept., Pennsylvania Power & Light Co., Allentown, Pa.

Mohaupt, R. E., elec. engr., Harnischfeger Corp., Milwaukee, Wis.

Morgan, J. S., engr.-in-chge., switchgear sales, Allis-Chalmers Mfg. Co., Milwaukee, Wis.

Mouromtseff, I. E., asst. to mgr., electronics engg. dept., Westinghouse Elec. Corp., Bloomfield, N. J.

Munzer, L. F., major, Air Corps, U. S. Army, Pacific Div., Air Transport Command, San Francisco, Calif.

Norell, E. G., elec. engr., Sargent & Lundy, Chicago, Ill.

Oehrig, H. B., resident engr., E-J Elec. Installation Co., Jeffersonville, Ind.

Pollard, C. L., sr. engr., engg. dept., Pennsylvania Power & Light Co., Allentown, Pa.

Pratt, W. E., asst. overhead engr., Memphis Lt. Gas & Water Div., Memphis, Tenn.

Road, R. A., chief engr., Duncan Elec. Mfg. Co., Lafayette, Ind.

Robinson, J. M., elec. engr., North Elec. Mfg. Co., Galion, Ohio

Roehm, F. J., elec. engr.-designer, American Machine & Foundry Co., Brooklyn, N. Y.

Ryder, J. D., prof. of elec. engg., Iowa State College, Ames, Iowa

Shaad, P. E., elec. engr., Sacramento Municipal Utility District, Sacramento, Calif.

Smith, W. T., assoc. engr., Rural Electrification Administration, Washington, D. C.

Snead, S. R., erection engr., Allis-Chalmers Mfg. Co., Milwaukee, Wis.

Summers, I. A., captain, AC, AAF Liaison Officer, Radio Research Lab., Harvard Univ., Cambridge, Mass.

Thomas, E. A., testing engr. & meter supt., Walsall Corp., Elec. Supply Dept., Walsall, Staffs, England

Thrithart, J., field engr., General Elec. Co., St. Louis, Mo.

Tracht, P. A., laboratory director, Evant Products Co., Detroit, Mich.

Troche, H., field service engr., Westinghouse Elec. Corp., Milwaukee, Wis.

Waddell, J. D., asst. operating mgr., electric, Delaware Power & Light Co., Wilmington, Del.

West, B. C., lt. comdr., USNR, Puget Sound Navy Yard, Bremerton, Wash.

Wood, M. M., head, elec. equip. section, Cornell Aeronautical Lab., Buffalo, N. Y.

51 to grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Any member objecting to the election of any of these candidates should so inform the secretary before May 15, 1946, or July 15, 1946, if the applicant resides outside of the United States or Canada.

To Grade of Member

Anderson, G. H., Rural Electrification Adm., Washington, D. C.

Anderson, L. W. W., Messrs. Veritys Ltd., Birmingham, England

Aspden, R. L., Royal Aircraft Establishment, Farnborough, Hants, England
Armstrong, W. B., Capt., USNR, Bureau of Ships, Navy Dept., Washington, D. C.
Baker, W. R., Atlantic Coast Line Railroad Co., Wilmington, N. C.
Brasfield, C. T., Jr., Alabama Power Co., Birmingham, Ala.
Bray, W. H., Air Ministry, West Drayton, Middlesex, England
Burrier, E. R. (re-election), Hudson Coal Co., Scranton, Pa.
Campbell, C. F., Puebla Tramway Light & Power Co., Puebla, Mexico
Carlock, L. H., Jr., TVA, Jackson, Tenn.
Cope, R. R., Aluminum Co. of America, New Kensington, Pa.
Court, E. T., The Radio Gramophone Development Co., Bridgnorth, Shropshire, Eng.
Dabney, T. S., General Electric Co., Beaumont, Tex.
Decker, H. J., General Motors Corp., La Grange, Ill.
Double, C. R., Bonneville Power Adm., Portland, Oreg.
Erickson, E. H., Public Service Elec. & Gas Co., Newark, N. J.
Gilcreese, O. E., Tennessee Eastman Corp., Oak Ridge, Tenn.
Giorgi, L., General Rio Negro Hydro Development, Montevideo, Uruguay
Hall, W. C., Naval Research Lab., Anacostia Sta., Washington, D. C.
Hansen, P. B. (re-election), Graybar Elec. Co., Inc., Minneapolis, Minn.
Harrison, A. M., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Havart, R. F., Govt. of Bahamas Elec. Dept., Nassau, Bahamas, B. W. I.
Hill, T. H., Ferranti Electric Ltd., Toronto, Ont., Can.
Hommel, R. W., War Dept., Wright Field, Dayton, Ohio
Howard, D. J., Cornell Aero. Lab., Buffalo, N. Y.
Kirk, H. H., Kellex Corp., New York, N. Y.
Leatham, W. T., Consumers Power Co., Jackson, Mich.
Luquse, E. D., Industria Electrica de Mexico, S. A., Mexico City, Mexico
Manahan, F. T., Albert Kahn, Assoc. Architects & Engineers, Inc., Detroit, Mich.
Mathieu, H. P., Cabot Shops, Inc., Pampa, Tex.
McKay, J. W., Tampa Elec. Company, Winter Haven, Fla.
Merritt, A. O., Humber-Hillman Co. Ltd., Stoke, Coventry, England
Metcalf, C. N., Consolidated Edison Co. of New York, New York, N. Y.
Miller, F. G., Cruft Lab., Harvard University, Cambridge, Mass.
Miller, G. B., Duquesne Light Co., Pittsburgh, Pa.
Myers, V. E., Cutler Hammer, Inc., Milwaukee, Wis.
Richards, R. T., Central Arizona Light and Power Co., Phoenix, Ariz.
Sarault, G. E., Université Laval, Quebec, P. Q., Canada
Sharpless, H. R., Sr., Gulf Oil Corp. Refinery, Port Arthur, Tex.
Swartzel, K. D., Cornell Aeronautical Lab., Cheektowoga, N. Y.
Taylor, J. D., Alden Park Manor, Philadelphia, Pa.
Tantawi, M. K. M., Eastern Elec. Co., Cairo, Egypt
Teach, E. B., Ingersoll-Rand Co., Painted Post, N. Y.
Varma, R. P., The Gaya Electric Supply Co. Ltd., Gaya, Bihar, India
Walmsley, F. C., The Micanite and Insulators Co., Ltd., Walthamstow, London, England
Wang, H. W., Natl. Resources Comm. of China Technical Office, New York, N. Y.
Weichel, T. R., U. S. Bureau of Mines, Mount Hope, W. Va.
Woodward, W. B., The Ohio Bell Tel. Co., Cleveland, Ohio
Worstell, R. E., General Elec. Co., New York, N. Y.
Wunenburger, G., Buenos Aires University, Buenos Aires, S. A.
Zak, S. J., Wright Field, Dayton, Ohio
51 to grade of Member

To Grade of Associate

United States and Canada

1. North Eastern

Bliss, J. A., W. S. Rockwell Co., Fairfield, Conn.
Bloom, J. H., Sylvania Electric Products, Inc., Boston, Mass.
Claschini, W. A., General Elec. Co., Pittsfield, Mass.
Cochran, J. L., General Elec. Co., Schenectady, N. Y.
Davies, A. E., Cornell University, Ithaca, N. Y.
Dawson, C. H., University of Rochester, Rochester, N. Y.
Dodge, F. T., Aluminum Co. of America, Massena, N. Y.
Feigenbaum, A. V., General Elec. Co., Schenectady, N. Y.
Field, S. W., Miller & Seddon Co., Inc., Cambridge, Mass.
Goode, J. J., Dodcam, Inc., West Newton, Mass.
Gregg, V. F., General Elec. Co., Schenectady, N. Y.
Haddad, A., International Business Machines Corp., Endicott, N. Y.
Hall, C. M., Cutler Hammer, Inc., Boston, Mass.
Hawthorne, R. P., Defender Div., E. I. du Pont de Nemours & Co., Inc., Rochester, N. Y.
Jester, L. T., Jr., General Elec. Co., Boston, Mass.
Kaufmann, W. C., Westcott and Mapes, Arch. & Eng., New Haven, Conn.
Malkowski, H. F., Blackstone Valley Gas & Elec. Co., Pawtucket, R. I.
O'Brien, F. A., Stone & Webster Engg. Corp., Boston, Mass.
Pallace, R. V., General Electric Co., New Haven, Conn.
Peterson, A. W., Chas. T. Main, Inc., Boston, Mass.
Pierce, R. M., General Elec. Co., Schenectady, N. Y.
Rittenhouse, H. J., Schiefer Elec. Co., Inc., Rochester, N. Y.
Rose, S. H., Bendix Aviation Corp., Norwood, Mass.
Schmidt, G. F. (re-election), Cutler-Hammer, Inc., Buffalo, N. Y.
Seasly, E. R., General Elec. Co., Pittsfield, Mass.
Short, W. A., Ens., USNR, 218 Buckingham Ave., Syracuse, N. Y.
Sonntag, J. C., The Hartford Elec. Light Co., Hartford, Conn.
Steele, H. S., General Elec. Co., Schenectady, N. Y.
Straughn, R. Y. (Miss), General Elec. Co., Schenectady, N. Y.
Turrentine, R. E., General Elec. Co., Schenectady, N. Y.
Van Iderstine, W. W., Westcott & Mapes, Inc., New Haven, Conn.
Vershbow, D. R., Modern Die & Machine Co., Boston, Mass.
Wagener, J. A., Crocker-Wheeler Elec. Manufacturing Co., Boston, Mass.
Welsh, J. P., Cornell Aeronautical Lab., Buffalo, N. Y.
Whitney, D. C. (re-election) City of Burlington Elec. Light Dept., Burlington, Vt.
Worcester, R. J., General Elec. Co., Schenectady, N. Y.

2. Middle Eastern

Aldrich, D. F., Westinghouse Elec. Co., Pittsburgh, Pa.
Baker, J., B. F. Goodrich Co., Akron, Ohio
Barnaby, D. R. E., Central Ohio Light & Power Co., Findlay, Ohio
Barter, L. D., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Bechtold, D. J., Northern Pennsylvania Power Co., Towanda, Pa.
Bennett, J. L., Black & Decker Mfg. Co., Towson, Md.
Berghausen, P. E., 444 Rawson Woods Lane, Cincinnati, Ohio
Bickham, A. S., The Master Elec. Co., Dayton, Ohio
Binson, B., Royal Siamese Legation, Washington, D. C.
Bohnert, J. L., Cleveland Elec. Illuminating Co., Cleveland, Ohio
Calderhead, H. J., Bird Electronics Corp., Cleveland, Ohio
Carlson, D. J., Navy Dept., Bureau of Ships, Washington, D. C.
Carney, R. R., General Elec. Company, Philadelphia, Pa.
Chelich, L., Westinghouse Elec. Corp., Pittsburgh, Pa.
Conrad, G. T., Jr., Herbert L. Wilson, Washington, D. C.
Davis, H. E., Boon County Coal Corp., Sharples, W. Va.
Dryden, G. G., Sperry Gyroscope Co., Inc., Baltimore, Md.
Dumont, R. A., Electric Repair Shop, Sparrows Point, Md.
Eaton, E. F., Jr. (ETM 3/O) Navy Dept., Bureau of Personnel, Washington, D. C.
Fetterman, C. D., Philadelphia Elec. Co., Philadelphia, Pa.
Flanagan, J. L., Ensign, USNR, Naval Research Lab., Washington, D. C.
Fox, J. M., Jr., Philadelphia Elec. Co., Philadelphia, Pa.
Freegard, E. M., General Elec. Co., Pittsfield, Mass.
Funk, R. W., Goodyear Tire and Rubber Co., Akron, Ohio
Hales, W. M., Jr., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Hamme, D. E., National Tube Co., McKeesport, Pa.
Handelman, J., Phila. Signal Corps Inspection Zone, Phila., Pa.
Heintz, C. A., Philadelphia Elec. Co., Philadelphia, Pa.
Heinz, L. R., General Elec. Co., Baltimore, Md.
Howenstine, W. L., Potomac Elec. Power Co., Washington, D. C.
Jackewicz, B. S., Elec. Controller & Mfg. Co., Cleveland, Ohio
Jeffrey, R. B., Line Material Company, Zanesville, Ohio
Judd, L. J., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Mack-Forlist, D. M., Bethlehem Steel Co., Baltimore, Md.
Mather, G. H. (re-election), Westinghouse Elec., Corp., Philadelphia, Pa.
McCorvey, W. H., American Tel & Tel. Co., Philadelphia, Pa.
McLaughlin, B. E., Public Utilities Div., U. S. Treasury Procurement, Washington, D. C.
Mickle, R. G., Philadelphia Elec. Co., Philadelphia, Pa.
Moll, W. H., Electro-Mechanical Instrument Co., Perkasie, Pa.
Monroe, J. W., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Nagel, C. E., Jr., Westinghouse Elec. Corp., Pittsburgh, Pa.
Palmer, J. B., Jr., Drexel Institute of Technology, Philadelphia, Pa.
Pearce, J. W., The Hoover Co., North Canton, Ohio
Plaisted, R. G., University of Pittsburgh, Pittsburgh, Pa.
Prior, C. A., The Elec. Products Co., Cleveland, Ohio
Ruger, H. D., Bethlehem Steel Co., Sparrows Point, Md.
Schwartz, D. E., USN, Bureau of Ordnance, Washington, D. C.
Scott, A. L., Westinghouse Corp., East Pittsburgh, Pa.
Shawkins, W., Carbide & Carbon Chemicals Corp., S. Charleston, W. Va.
Shuster, D., War Dept., Phila. Sig. C., Inspection Zone, Philadelphia, Pa.
Smith, A. T., British Overseas Airways Corp., Baltimore, Md.
Sparlin, B. J., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Stewart, D. F., Consulting Engineering Co., Inc., Pittsburgh, Pa.
Studer, J. V., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Sucharski, W. T., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Van Arkell, J. C., Jr., Erie Resistor Corp., Erie, Pa.
Wagner, I. B. (re-election), Lima Locomotive Works, Inc., Lima, Ohio.
Watson, R. E., Leeds & Northrup Co., Philadelphia, Pa.
Willmott, L. J., Firestone Tire & Rubber Co., Akron, Ohio
Zanzie, C. E., United Engineers & Constructors, Phila., Pa.

3. New York City

Bates, S. C., Bell Telephone Labs., New York, N. Y.
Blaiklock, W. J., General Elec. Co., New York, N. Y.
Brooks, G. (Miss), Sperry Gyroscope Company, Great Neck, L. I., N. Y.
Brown, W. E., Raymond M. Wilmotte, Inc., New York, N. Y.
Carfolite, E. D., 571 West 215 St., New York, N. Y.
Cavallaro, S., Lieut. (jg), U.S.N.R., 1326 Morrison Ave., Bronx, N. Y.
Cox, J. L., Duro Test Corp., North Bergen, N. J.
Deering, N. J., Jr., Public Service Elec. & Gas Co., Irvington, N. J.
Feldman, S., 2162 Prospect Ave., Bronx, N. Y.
Friedman, J. G., Heyer Products, Inc., Belleville, N. J.
Granat, E. M., R.C.A., Victor Division, Camden, N. J.
Gropp, G. J. (re-election), National Lead Co., New York, N. Y.
Hailperin, C. B., Vascoloy-Ramet Corp., New York, N. Y.
Lee, J., Century Lighting, Inc., New York, N. Y.
Long, L. A., Radio Corp. of America, Camden, N. J.
MacInnes, D., International General Elec. Co., New York, N. Y.
Mahler, B. B., Federal Telephone & Radio Corp., Newark, N. J.
McCabe, W. R., Lord Elec. Co., Inc., New York, N. Y.
Metzger, C., Hatzel & Buehler, Inc., New York, N. Y.
Ni, C. H., National Resources Comm. of China, Technical Office, New York, N. Y.
Perkowski, S., Western Elec. Co., Inc., New York, N. Y.
Pilugeisen, K., Curtis Elevator Co., Long Island City, N. Y.
Rau, L. E., Lieut., USNR, 121 Birchwood Dr., Belleville, N. J.
Redfern, R. E., U. S. Army Signal Corps Engineering Labs., Ft. Monmouth, N. J.
Sabol, M. W., New York Naval Shipyard, Brooklyn, N. Y.
Sielski, A. T., Bremer Broadcasting Co., Station WAAT, Newark, N. J.
Stega, E. A., Coles Signal Laboratory, Red Bank, N. J.
Stevens, B. C., Jr., Heather Drive, Mahopac, N. Y.
Theobald, G., Public Service Elec. & Gas Co., Newark, N. J.
Tsao, Y., National Resources Comm. of China, New York, N. Y.
Weiss, E., 326 St. Johns Place, Brooklyn, N. Y.
Zellar, G., Western Elec. Co., Inc., New York, N. Y.

4. Southern

Brinson, A. P., Commonwealth & Southern Corp., Birmingham, Ala.
Buford, W. H., Southern Advance Bag and Paper Co., Inc., Hodge, La.
Burnett, B., General Elec. Co., Roanoke, Va.
Coburn, J. E., Alabama Power Co., Birmingham, Ala.
Crescenzi, A. H., Tennessee Eastman Corp., Knoxville, Tenn.
Cullick, I., 557 Forest Avenue, Shreveport, La.
Daniels, A. B., Jr., Schlumberger Well Surveying Corp., Houma, La.
Duffy, J. F., Jr., Sperry Gyroscope Co., Norfolk, Va.
Foster, E. B., Box 549, Sheffield, Ala.
Fox, G. B., Jr., Tennessee Eastman Corp., Oak Ridge, Tenn.
Haller, M. N., U. S. Navy, Bananariver, Fla.
Halsted, B. C., Allis-Chalmers Mfg. Co., Richmond, Va.
Harshbarger, C. K., Sr., Hercules Powder Co., Hopewell, Va.
Horton, J. L., Tenn. Eastman Corp., Oak Ridge, Tenn.
Huguenin, F. B., Florida Power & Light Co., Sarasota, Fla.

Johnson, E. D., Georgia Power Company, Rome, Ga.
Keane, R. J., National Advisory Committee for Aeronautics, Langley Field, Va.
Lacy, J. W., Jr., General Elec. Co., Birmingham, Ala.
La Londe, J. W., USS Leyte, c/o Newport News Shipbuilding & Drydock Co., Newport News, Va.
Lapidus, M., The Engineer Board, Fort Belvoir, Va.
Matthews, W. A., Duke Power Company, Charlotte, N. C.
Morton, A. G., Birmingham Elec. Co., Birmingham, Ala.
Murray, I. R., Tennessee Valley Authority, Chattanooga, Tenn.
Nalley, J. R., Allis-Chalmers, Louisville, Ky.
Neighbors, E. S., Birmingham Elec. Co., Birmingham, Ala.
Pentecost, J. R., Escambia River Elec. Co-operative, Jay, Fla.
Scharres, E. H., Carbide & Carbon Chemicals Corp., Oak Ridge, Tenn.
Shaw, J. D., Va. Elec. & Power Co., Richmond, Va.
Sheap, D. S., Va. Elec. & Power Co., Richmond, Va.
Strock, H. E., E. H. Gilliam & Company, Charlotte, N. C.
Stubblebine, C. A., Georgia Power Co., Atlanta, Ga.
Wagner, R. F., Tennessee Eastman Corp., Oak Ridge, Tenn.
Webb, A. O., University of Tennessee, Martin, Tenn.
Wendel, D. D., Alabama Power Co., Birmingham, Ala.
Woodcock, W. I. (re-election), Alabama Power Co., Birmingham, Ala.

5. Great Lakes

Barlett, T. A., AC Spark Plug Div. of G.M., Flint, Mich.
Blanford, E. C., Clay's Radio Service, Flint, Mich.
Bridges, R. B., Cutler-Hammer, Inc., Milwaukee, Wis.
Bruesch, R. V., Mattison Machine Works, Rockford, Ill.
Copeland, M. J., Commonwealth Edison Co., Chicago, Ill.
Cushead, S. A., Central Illinois Elec. & Gas Co., Rockford, Ill.
Culhane, J. L., Iowa Power and Light Co., Des Moines, Iowa
Day, C. C. (re-election), Consumers Power Co., Grand Rapids, Mich.
Durbin, H. M., R.C.A. Victor, Indianapolis, Ind.
Ekstrom, I. F., Commonwealth Edison Co., Chicago, Ill.
Evans, F. M., III, U. S. Engineer Office, Rock Island, Ill.
Evans, J. T., Bull Dog Elec. Products Co., Detroit, Mich.
Fink, W. G., Harnischfeger Corp., Milwaukee, Wis.
Flanigan, A. R., Jr., Commonwealth & Southern Corp., Jackson, Mich.
Fowler, R. J., Consumers Power Co., Flint, Mich.
Freeck, A. A., Harnischfeger Corp., Milwaukee, Wis.
Freeman, A., Carnegie Illinois Steel Corp., Chicago, Ill.
Gerber, J. H., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Honeywell, S. W., Sargent & Lundy, Chicago, Ill.
Hosier, H. A., General Elec. Co., Ft. Wayne, Ind.
Imbertson, J. R., Elec. Machinery Mfg. Co., Minneapolis, Minn.
Jacobs, W. E., Consumers Power Co., Jackson, Mich.
Jacobson, R. R. (re-election), General Elec. Co., Duluth, Minn.
Jefferis, T. K., Village of Grosse Pointe Shores, Mich.
Johnson, W. M., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Kaufman, I., RCA Victor, Indianapolis, Ind.
Kirchmayer, L. K., Cutler-Hammer, Inc., Milwaukee, Wis.
Kirk, Harold, Public Service Co. of No. Ill., Chicago, Ill.
McDonald, R. E., Northwest Airlines, Minneapolis, Minn.
Middleton, W. B., Michigan Bell Telephone Co., Detroit, Mich.
Miller, C. E., Purdue University, Lafayette, Ind.
Nemec, G. W., White City Elec. Co., Chicago, Ill.
Noonon, R. F., Michigan State College, East Lansing, Mich.
Pohnan, F. J. (re-election), Commonwealth Edison Co., Chicago, Ill.
Rhodes, E. F., Jr., General Elec. Co., Fort Wayne, Ind.
Risley, M. I., N. W. Bell Telephone Co., Minneapolis, Minn.
Sarvasy, H., 2900 Hazelwood, Detroit, Mich.
Schoonover, O., Melborn Development Co., Melrose Park, Ill.
Schwantz, W. G., Commonwealth Edison Co., Chicago, Ill.
Sibley, S. J., City Water, Light & Power, City of Springfield, Ill.
Simmons, C. R., U.S.N.T.C., Great Lakes, Ill.
Sly, R. M., Southern Indiana Gas & Elec. Co., Evansville, Ind.
Smith, L. B., AC Spark Plug Div. of G.M., Flint, Mich.
Thiemann, V., Wisconsin Public Service Corp., Green Bay, Wis.
Vaclavik, F. J. (re-election), The Commonwealth & Southern Corp., Jackson, Mich.
Williamson, R. M., Commonwealth Edison Co., Chicago, Ill.
Woodward, W. V., Northern Indiana Public Service Co., Hammond, Ind.

6. North Central

Beck, H. A. Bureau of Reclamation, Denver, Colo.
Bogard, J. E., Platte Valley Public Power & Irrigation Dist., McCook, Nebr.
Dieaman, A. D., Bureau of Reclamation, Denver, Colo.
Fallon, J. L., Bureau of Reclamation, Denver, Colo.
Goodrich, R. D., Jr. (re-election), U. S. Bureau of Reclamation, Denver, Colo.
Staab, M. L., Northwestern Bell Telephone Co., Omaha, Nebr.
Ungemach, C. D., Mountain State Telephone & Telegraph Co., Denver, Colo.
Williamsen, A. S., U. S. Bureau of Reclamation, Denver, Colo.

7. South West

Agnew, G. C., Carter Oil Company, Tulsa, Okla.
Bressler, H., White-Rodgers Elec. Company, St. Louis, Mo.
Brothers, C. E., Harvill-Byrd Electric Co., Little Rock, Ark.
Carter, F., Capt., Field Artillery School, Ft. Sill, Okla.
Cordsen, F. C., Gulf States Utilities Co., Beaumont, Tex.
Deam, A. P., University of Texas, Austin, Tex.
Dickinson, F. C., Army Air Forces, Tinker Field, Okla. City, Okla.
Dumanian, J. A., Manhattan Project, Santa Fe, N. Mex.
Floyd, R. G., Jr., Humble Pipe Line Co., Houston, Tex.
Hartwell, G. E., The Mine & Smelter Supply Co., El Paso, Tex.
Hentchel, T. P., National Geophysical Co., Inc., Dallas, Tex.
Hiestand, W., Capt., Signal Corps, U.S.A., 7542 Trenton Ave., University City, Mo.
Hill, S. W., Okla. Gas & Elec. Co., Shawnee, Okla.
Hole, W. G., Southwestern Bell Telephone, Topeka, Kan.
Huller, R. W., Westinghouse Electric Corp., Kansas City, Mo.
Jackson, M. F., Jr., Jackson Elec. Co., El Reno, Okla.
Kaelin, J. A., Kansas City Power & Light Co., Kansas City, Mo.
Kreppel, B. W., Seismograph Service Corp., Tulsa, Okla.
Krachmalnick, F., White-Rodgers Elec. Co., St. Louis, Mo.
Laughlin, J. R., General Elec. Co., Tulsa, Okla.
Lee, H. J., Consolidated Vultee Aircraft Corp., Fort Worth, Tex.
Lynn, L. C., Southwestern Bell Tel. Co., Okla. City, Okla.
Phillips, E. B. (re-election), P. O. Box 483, Stillwater, Okla.
Poolman, J. R., Int. Business Machines Corp., Little Rock, Ark.
Poore, J. N., General Electric Co., Dallas, Tex.
Rich, F. A., Okla. Gas & Elec. Co., Okla. City, Okla.
Rumans, W. W., Burns-McDonnell Consulting Eng. Co., Kansas City, Mo.
Sheeters, O. C., Williamson Sales Co., Dallas, Tex.
Snow, J. H., Dow Chemical Co., Freeport, Tex.
Sorkness, R. E., Base Shops, Randolph Field, Tex.
Stephenson, L. J., U. S. Air Forces, Randolph Field, Tex.
Van Citzen, M. E., James R. Kearney Corp., St. Louis, Mo.
Wagner, C. M., R.E.A. Co-operative, Inc., Robstown, Tex.
Wiggins, T., Lower Colorado River Authority, Austin, Tex.
Yang, C. F., TWA Base Engineering Division, Kansas City, Mo.

8. Pacific

Aspinwall, J., Railroad Commission, San Francisco, Calif.
Baldasari, C., The Kerite Co. of New York, San Francisco, Calif.
Brooks, G. R., Allis-Chalmers Mfg. Co., San Francisco, Calif.
de Laneux, H. H., Pacific Gas & Elec. Co., Emeryville, Calif.
Derin, H. H., Fluor Corp. Ltd., Los Angeles, Calif.
Farnham, E. V., Natomas Co., Natoma, Calif.
Garafalo, J. J., Universal Microphone Co., Inglewood, Calif.
Lerner, J., U. S. Naval Base, Terminal Island, Calif.
McComber, L., Pacific Gas & Elec. Co., Sacramento, Calif.
McKnight, R. J., Central Arizona Light & Power Co., Phoenix, Ariz.
Moore, E. J., U. S. Navy Electronics Laboratory, San Diego, Calif.
Ohlson, R. E., General Elec. Co., San Francisco, Calif.
Osen, L. C., 900 Bay St., San Francisco, Calif.
Peterson, W. E., USNR, c/o AIM, AEO, San Francisco, Calif.
Ridgway, R. L., Bethlehem Steel Co., Terminal Island, Calif.
Schick, W. H., General Elec. Co., San Francisco, Calif.
Scogging, G. W., Jr., Lieut., N.A.S., Alameda, Calif.
Sears, T. B., U. S. Bureau of Reclamation, Boulder City, Nev.
Van Winkle, W. J., Natomas Co., Natoma, Calif.
Viehe, F. W., 1009 West Madison St., Phoenix, Ariz.
Wilkie, D. F. (re-election), Salt River Valley Water Users Assn., Phoenix, Ariz.

9. North West

Anderson, T. L. (re-election), Provo City Department of Utilities, Provo, Utah
Boatman, A. R., Puget Sound Power & Light Co., Dieringer, Wash.
Clifton, G. M., General Elec. Co., Seattle, Wash.
Conway, H. E., Bonneville Power Administration, Portland, Oreg.
Crosier, R. D., General Elec. Company, Spokane, Wash.
Davies, I. T., Bonneville Power Administration, Portland, Oreg.
Duvall, A. D., Ens., USNR, 805 N. Church St., Salem, Oreg.
Hall, W. P., 3645 Simmers Avenue, Klamath Falls, Oreg.
Heym, D. E., U. S. Engineer Office, Portland, Oreg.
Kessler, A. W., Westinghouse Elec. Corp., Portland, Oreg.
Lienert, J. T., Supervisor of Shipbuilding, USN, Portland, Oreg.
Mageehon, O., Willamette Iron & Steel Corp., Portland, Oreg.
Poland, M. G., Bonneville Power Adm., Portland, Oreg.
Sandberg, J. W., General Elec. X-Ray Corp., Seattle, Wash.
Shanks, C. K., Ensign, USN, 3338 N.W. Franklin Ct., Portland, Oreg.
Wild, W. F., Willamette Iron & Steel Corp., Portland, Oreg.

10. Canada

Cahn, P. R. G., University of Toronto, Toronto, Ont., Can.
Creed, F. C., National Research Council, Ottawa, Ont., Can.
Gordon, L. M., Hydro-Electric Power Comm. of Ontario, Toronto, Ont., Can.
Graham, A., Amalgamated Elec. Corp. Ltd., Toronto, Ont., Can.
Jones, W. E., Ont. Hydro Power Comm., Toronto, Ont., Can.
O'Brien, E. W., Shawinigan Water and Power Company, Trois Rivieres, Que., Can.
Palmer, E. B., Ford Motor Co. of Canada, Ltd., Windsor, Ont., Can.
Pringle, E. W., Hydro-Elec. Power Comm. of Ont., Toronto, Ont., Can.
Purvis, W. J., National Research Council, Ottawa, Ont., Can.
Roper, A. J., Crossman Machinery Co., Vancouver, B. C., Can.
Saffrey, R. H., Fetherstonhauch & Co., Toronto, Ont., Can.
Switzer, W. E., Canadian Pacific Railway, Toronto, Ont., Can.

Elsewhere

Agustsson, I., Reykjavik Municipal Electric Light & Power Works, Reykjavik, Iceland
Casares, A., General Elec. S. A., Mexico, D. F., Mex.
Cimet, L., H., The General Supply Co., Mexico City, Mex.
Ghosh, C. S., Calcutta University, Kalighat, Calcutta, India
Gleeson, J., P. O. Engineering Dept., Dublin, Eire
Hawgood, B. V., Westinghouse Elec. International Co., Bakhtar, S. Rhodesia
Herrera, A., E., Westinghouse Elec. Intl. Co., Mexico City, Mex.
Hierro A., Ignacio, Public Water Works of City Govt., Tacubaya D. F., Mex.
Hubard, E., Hubard & Bourlon Sucrs., S. A., Mexico, D. F., Mex.
Lee, C., Cerro de Pasco Copper Corp., La Oroya, Peru, S. A.
Moconduy, M. M., Puerto Rico Water Resources Authority, Santurce, P. R.
Perea, E. M., Nicaro Nickel Co., Nicaro, Oriente, Cuba
Lowe, R. D., Ministry of Munitions, Sydney, N. S. W., Australia
Osante O., P., Union Mercantil, S. A., Monterrey, N. L., Mex.
Pully, L. S., Jr., USN, 17th Naval District, Kodiak, Alaska
Punter, H., Messrs. Falk Stadelmann & Co. Ltd., Birmingham, England
Rodriguez, M. A., National Institute of Cardiology, Mexico City, Mex.
Romero M., J., Victoria #37-D, Mexico City, Mex.
Rowsey, H. J., Army Headquarters, Wellington, New Zealand
Sampson M., E., General Electric S. A., Mexico City, Mex.
Sathar, S. A., Telegraphs (Govt. of India), Bangalore, India
Sharma, B. R., Punjab P. W. D., Electricity Branch, Lahore, India
Spindola L., R., Westinghouse Elec. Intl. Co., Mexico City, Mex.
Subramaniam, R., M. E. S., Office of Garrison Engineer, Hospital Town, Bangalore, India
Voyles, J. E., All America Cables & Radio, Inc., Lima, Peru, S. A.
Wilson, K. A., State Hydro-Electric Dept., Wellington, New Zealand

Total to grade of Associate
United States and Canada, 302
Elsewhere, 26

OF CURRENT INTEREST

Co-operation Ahead for ASA and Commerce Department

A partial reorganization of the Department of Commerce and ASA facilities for preparation of standards which was set in motion by a report of the Policy Committee on Standards appointed by Secretary of Commerce Henry Wallace in 1945 places Government approval on voluntary action by industrial groups as the most desirable basis for determining industrial and consumer standards.

In reports made to Mr. Wallace in June and December 1945, the chairman of the policy committee, Charles E. Wilson, president of the General Electric Company, recommended that standards submitted to the Department of Commerce for development or publication by consumer or industrial groups be referred to the American Standards Association by either the sponsoring group or the Department for approval and publication as American Standards. If the sponsoring group desires publication of the standard before its acceptance as an American Standard, the later Wilson report recommends that this be done by the interested group and not under the name of the Department of Commerce. In this connection the report points out that publication by the Commerce Department often leads to acceptance of the standards as ones developed and approved or enforced by the Government, whereas they are only records of voluntary trade group action. The report recognizes the need for a revision of ASA facilities to encompass the recommended scope of activity.

It recommends the transfer of the divisions of Simplified Trade Practices and Commercial Standards from the National Bureau of Standards.

In accordance with Mr. Wilson's proposals, Mr. Wallace has agreed that the maximum support be given to ASA activity to strengthen its position as the fountainhead of standardization work in the country. In a letter to Mr. Wilson he proposes that "to the extent that the American Standards Association reorganizes its procedures in accordance with the recommendation of your Committee so that it can perform trade standard services to the satisfaction of all the groups with an interest in standards, the Department is prepared to encourage the use of the facilities of the American Standards Association for the initiation, development, and publication of standards." Mr. Wallace further states "the Department would be prepared as a matter of policy to suggest when the Association's facilities are adequate that standards be submitted to the ASA for publication as American Standards." At the same time he would leave freedom of choice in the matter to the sponsoring business group.

As evidence of his desire to co-operate with the ASA, Mr. Wallace suggests "that a joint conference committee of the ASA and the Department be set up for this purpose. I believe that this conference committee should cover the entire field of standards—the scientific, technical, and testing aspects as well as the economic marketing and trade aspects of the problem—and that the Department's representatives on the committee therefore should include scientists of the National Bureau of Standards as well as officials of the Office of Domestic Commerce, Office of the Solicitor, and the Office of Program Planning."

As Mr. Wilson recommended, the divisions of Simplified Trade Practices and Commercial Standards have been transferred from the National Bureau of Standards to the new Office of Domestic Commerce. Such voluntary standards as these divisions will be requested to publish will be printed by the Department of Commerce and not by the National Bureau of Standards, which should lead to less confusion about the status of such standards. Credit for any research work it may perform will be given to the Bureau. The two divisions will continue to sponsor and perform basic research in the economic and marketing fields for ASA and other groups formulating standards and will propose standards to the ASA.

Mr. Wallace adds that he does not believe the Department can ignore industry and economic groups that request its assistance which is a statutory responsibility. For this reason some Departmental publication activity will be continued.

He is in accord with the Wilson report's definition of the Bureau of Standards functions as those of basic research, furnishing of facts, measurements, and technical assistance in the development of adequate testing methods, expresses approval of the expansion and improvement of voluntary industrial standardization activity, and sees the Department's role as one of encouraging and stimulating such activity.

In announcing ASA's full co-operation with Mr. Wallace's views, Henry B. Bryans, ASA president, enumerated the steps already taken in strengthening the Association along the lines of the Policy Committee's recommendations.

Through a change in its constitution, the ASA has broadened the scope of its work, so that it may deal with any standards or standardization projects deserving national recognition, whether in the field of engineering, consumer goods, or in other fields.

The representative character of the ASA board of directors is being rounded out by adding a consumer leader, a retailer, and a publisher of a national magazine. The principal consumer and other groups concerned are represented on the main ASA committee on consumer standards. Methods of work have been streamlined.

The representative character of the ASA has been broadened by membership of thirteen additional national organizations in the last year bringing the total to 94 national organizations.

Plans are already under way to expand the ASA financial structure, as well as to broaden the incidence of support and participation in the ASA.

An executive committee headed by Howard S. Coonley has been entrusted with the task of making provision for meeting the greatly increased responsibilities placed upon the Association by the Wilson report. Mr. Coonley, past president of the ASA and the National Association of Manufacturers, has just retired from the position of chairman of the board of the Walworth Company and plans to devote most of his time to directing the ASA development program. During World War II he headed the conservation, standardization, simplification, and specification work of the War Production Board and was advisor to the Chinese Government in setting up its War Production Board.

A start on standards for consumer goods has been made. These include such subjects as: safety shoes for men and women, women's industrial clothing, and a comprehensive set of specifications for gas burning appliances.

Among the subjects now under development are: specifications for electrical appliances, methods of test and terms for describing color fastness, and definition of textile terms used in the retail trade.

A Standard designed for the protection of the public in advertisements containing statements of approval by laboratories and similar means, such as "Approved by . . .," "Guaranteed by . . .," "Certified by . . .," is nearly ready for formal approval as an American Standard. The greater part of the work of the ASA, however, remains in the industrial field.

New methods of carefully controlled service tests, coupled with some of the newer specialized methods of market research, are being used extensively by some manufacturers and distributors. These, together with the research activities which Secretary Wallace is organizing in the Department of Commerce, and similar activities on the part of business groups, promise to make available for work on consumer standards constructive facilities that hitherto have been lacking in many fields.

Edison Association Endorses McMahon Bill

A special committee on appraisal of atomic energy, established by the Association of Edison Illuminating Companies to explore and appraise both the favorable possibilities and the limitations of atomic energy in the field of electric power supply, has endorsed the McMahon Bill (S1717) through its chairman John C. Parker (F '12) who recently testified before the United States Senate Committee on Atomic Energy on behalf of the association. The McMahon Bill would place control of atomic energy in a completely civilian agency, with a military section below the policy making level.

According to Doctor Parker, the committee which he represents is seeking to explore the probabilities of better service to the community and will avoid inquiry into the specific technique of the processing of fissionable materials or their utilization in fields other than that of heavy power generation. In this connection the committee is asking the assistance and advice of departments of the government as well as of scientists and engineers, and the design and other technical talent of the manufacturers.

"Most of the investment and much of the operating cost of present systems lie outside the generating plants—for example, in the distributing systems and in the multifarious services to the customers," said Doctor Parker in speaking of the economy of atomic energy. "There is no present indication that atomic energy will relieve that major element in cost. If this is correct then the primary advantage to the national economy will be in the service of that part of the utility load in which fuel costs play the relatively biggest parts, namely, industrial and heavy traction load, and the economies here probably will not be much greater than the difference in fuel cost."

Doctor Parker went on to clear up two popular misconceptions about atomic energy, one as to the amount of energy that would become available through atomic processes and the other that the public utilities might be unduly apprehensive of the obsolescence of their plant and property by a new technique.

"Never at any time," Doctor Parker stated, "has the United States suffered from a deficiency in the amount of power available. All that is necessary to expand the availability of electric power vastly is the construction of plants, transmission and distribution systems. Expansion of electric energy as a result of the development of atomic energy will occur, if at all, only after an extended period of time and as it proves economical."

In reference to the second "misconception" Doctor Parker explained that old boiler plant and combustion equipment may be removed, giving place to the newer type of boiler, with or without its own high-pressure high-temperature turbine. Thus steam would be produced for use in the present turbogenerators either directly or through the intervention of an atomic topping turbine.

"When it becomes reasonably certain that sound economic advantage will result from atomic sources," he continued, "it is fully expected that the rate of increase of central station energy utilization will make possible the introduction of atomic "toppers" for base load purposes, that is, for energy production round the clock so that the fullest operating advantage may be had from the replacement of the current conventional practices. It seems equally probable that the cost of new equipment will not be warranted or if so only in lesser degree by that part of the load which is of short duration. Thus, much of the unconverted present conventional equipment will represent the most realistically economical method of meeting the requirements of the community and therefore will have an undisturbed usefulness through its natural physical life."

However he added that "were the economic attractions of atomic energy in the course of time to prove so great that even peak load and reserve equipment would be forced into the scrap heap that fact itself would say that there were advantages sufficient to warrant the processes of supersession."

Doctor Parker declared that the public utility industry of the United States believes that atomic materials should be available for industrial use without differentiation as to the type of utility to which it is made available and with the single collateral requirement that any resultant net economics be passed on to the consumers under the supervision of regulatory authorities on the local level.

"As an association," he said, "we completely endorse the theory that the processing of such materials for use must be under the control of some such commission as is proposed in the Bill under discussion. The possibilities of misuse under any other scheme of production are too ghastly to be contemplated. As a collateral of such control, licenses for use seem quite inevitable. The greatest measure of effectiveness is, in our judgment, in the denial of release of materials to those who do not comply with the prescriptions."

Doctor Parker concluded, "The association does not offer comment at the present time on minor details of the McMahon Bill which it assumes will be modified somewhat, but regards the general structure of the Bill as most favorable to the orderly development of peaceful uses of a new technique which can be of great service to mankind."

The Association of Edison Illuminating Companies, sponsor of the special committee, is made up of member companies and operates primarily as a conference of executives with the assistance of the technical and commercial personnel of the member companies for the purpose of interchange of ideas and information. In addition to Doctor Parker, Consolidated Edison Company of New York, Inc., New York, N. Y., and AIEE Past-President, committee personnel includes Alex D. Bailey, Commonwealth Edison Company of Chicago, Chicago, Ill.; Kilshaw M. Irwin, Philadelphia Electric Company, Philadelphia, Pa.; James W. Parker, The Detroit Edison Company, Detroit, Mich.; and Philip Sporn (F '30) American Gas and Electric Service Corporation, New York, N. Y. Ward F. Davidson (F '26) Consolidated Edison Company of New York, Inc., is committee secretary.

AAF Studies Radar Navigation Systems. As the result of a recent five-day conference between Army Air Forces officers and leading manufacturers of radar equipment to determine the best radar system of air navigation for all-weather flying, the AAF will set up a technical committee to study all systems presented. Demonstrations will be held at Wright Field, Dayton, Ohio.

FTC Supports Patent Law Revision

Endorsement of seven proposals for patent legislation by the Federal Trade Commission in its annual report to Congress constitutes the opening gun in a new campaign to obtain drastic overhauling of the patent laws, according to a recent report of the National Patent Council.

In emphasizing the importance of FTC approval for the proposed changes, the Patent Council points out that the FTC always has obtained its appropriations from Congress without question. It works and co-operates closely with Congress, and two of its five members are former members of the House—William A. Ayers of Kansas and Ewin Davis of Tennessee. Key planner of the Commission's patent program is Willis J. Ballinger, economic adviser, formerly a member of the Temporary National Economic Committee which originally drafted the FTC's seven proposals.

The FTC concludes from the TNEC report that "the privilege accorded by the patent monopoly has been shamefully abused . . . that the privilege given has not been used as was intended by the framers of the Constitution and by the Congress, 'to promote the progress of science and the useful arts.' It has been used as a device to control whole industries, to suppress competition, to restrict output, to enhance prices, to suppress inventions, and to discourage inventiveness," FTC contends.

In submitting its recommendations, the FTC clarifies its position with the statement "that if the pattern of control which has been achieved through the patent monopoly continues in spite of the changes we suggest, a complete re-examination of our patent laws should be made with a view to

determining whether, under present-day conditions, they are calculated to achieve their avowed purposes."

"Indicated changes," the Committee report continues, "in the patent laws divide naturally into two general classes—procedural and substantive. In its preliminary report to the Congress, dated July 17, 1939, the Committee made certain recommendations with respect to the patent laws. Some of the procedural changes recommended have since become law. Subsequent examination of the problems has confirmed our belief that substantial changes are needed, including some in addition to those already recommended."

The seven proposals as sent to Congress follow:

"(*a*). *Licensing of Patents.* In order to eliminate the use of patents in ways inimical to the public policy inherent in the patent laws, as well as that of the anti-trust laws, we recommend that the Congress enact legislation which will require that any future patent is to be available for use by anyone who may desire its use and who is willing to pay a fair price for the privilege. Machinery, either judicial or administrative, should be set up to determine whether the royalty demanded by the patentee may fairly be said to represent reasonable compensation or is intended to set a prohibitive price for such use.

"This proposal is intended to prevent the suppression of patents as well as to provide for their availability for use in an equitable manner in any industry where they are a major factor.

"(*b*). *Unrestricted Licenses.* We recommend that the owner of any patent be required to grant only unrestricted licenses, and that he not be permitted to impose restrictions upon the buyer in sales of patented articles. There should be a further prohibition against any other restriction which would tend substantially to lessen competition or to create a monopoly, unless such restriction is necessary to promote the progress of science and the useful arts.

"(*c*). *Recording of Transfers and Agreements.* We recommend that any sale, license, assignment, or other disposition of any patent be evidence by an instrument in writing and that the same be required of any condition, agreement, or understanding relating to any sale or disposition of any such patent, and that in any such case a copy of such written instrument be filed with the Federal Trade Commission within 30 days after execution. There should, of course, be a substantial monetary penalty for failure to file as required.

"(*d*). *Limitation on Suits for Infringement.* In order to prevent the use of litigation as a weapon of business aggression rather than as an instrument for adjudicating honest disputes, we recommend legislation which will provide that no action based upon a charge of infringement of any patent, whether for damages, for an injunction, or for any other relief shall be permitted against any licensee under a patent or against any purchaser or licensee of any article unless the plaintiff has previously secured a judgment against the grantor of the license or the manufacturer of the article for infringement in connection with the granting of such licensee or the sale of such article.

"(*e*). *Forfeiture of Patent for Violation.* If any person who owns any interest in or right under a patent violates any of the prohibitions described in paragraphs (*a*) and (*b*) above, his interest therein should be forfeited, such forfeiture to be brought about in a civil action against such person by the United States. Any patent or interest therein so forfeited should become a part of the public domain.

"(*f*). *Single Court of Patent Appeals.* In order to improve the existing mechanism for the issuance of patents and the determination of disputes relating thereto, we recommend the creation of a single Court of Patent Appeals with jurisdiction coextensive within the United States and its territories. Such a court would replace the present 11 different and independent jurisdictions and should do much to assure uniform treatment of patents and to reduce the time and cost of patent litigation.

"(*g*). *Limitation on Period of Patent Monopoly.* The life of a patent should be so limited that it will expire not more than 20 years from the date of the filing of the application, thus obviating the possibility of prolonging the patent monopoly by keeping an application pending in the Patent Office. This would mean that if an application were kept pending in the Patent Office for more than three years, the 17-year term of the patent granted would be to that extent decreased."

New Research Bills Replace Kilgore and Magnuson Bills

A new bill, S1850, proposing the establishment of a National Science Foundation has been introduced into the Senate by Senators Kilgore, Magnuson, Johnson, Pepper, Fulbright, Saltonstall, Thomas, and Ferguson. S1850 is a revised composite of two bills introduced last July by Senators Kilgore and Magnuson, respectively, and incorporates elements of each. Ostensibly a compromise reconciling the essential differences and weaknesses of its predecessors as brought out in voluminous testimony, S1850 actually establishes precepts and procedures whereby government would have complete control not only of research, but of developments growing out of research. The Bill thus seems to renounce the recommendations made in previous hearings by a majority of scientists.

On the premise that a central scientific agency is necessary "to provide support for scientific research and development, to enable young men and women of ability to receive scientific training, to promote the conservation and use of the natural resources of the Nation, to correlate the scientific research and development programs of the several Government agencies, to achieve a full dissemination of scientific and technical information to the public, and to foster the interchange of scientific and technical information in this country and abroad," the bill sets up the Foundation, which is not to be an operating agency but rather serve to support research in existing organizations.

Administration of the proposed Foundation will be in the hands of a full-time salaried administrator appointed by the President and a National Science Board composed of nine members appointed by the President and the chairmen of the scientific committees heading the Divisions of the Foundation. The appointed members of the Board will serve on a part-time basis and will be so compensated. Their powers will be consultative and advisory.

Divisions of the Foundation enumerated in the bill are: Mathematical and Physical Sciences, Biological Sciences, Social Sciences, Health and Medical Sciences, National Defense, Engineering and Technology, Scientific Personnel and Education, and Publication and Information, and latitude is allowed for the formation of such additional division as may seem desirable. The provision is made that half of the members of the scientific committee for the Division of National Defense shall be civilians and half shall be appointees of the War and Navy Departments. Members of the Board and the divisional scientific committees will serve for three years with one third retiring each year.

The administrator is empowered to enter into contracts for financing or otherwise supporting research and development activities of other Government agencies or other organizations, to appoint a Deputy Administrator, to appoint the Directors of the Divisions, and the members of the divisional scientific committees. He must make an annual report to Congress and the President on the activities of the Foundation, including in it any dissenting opinions that may exist among the members of the Board or the divisional committees. He must maintain a register of scientific and technical personnel and in other ways provide a clearing house for information concerning scientific and technical personnel in the United States and its possessions. He may make contracts through the Department of State to co-operate in appropriate international research or developmental activities. He is authorized to award scholarships and fellowships to persons for scientific study or scientific work in any field of science.

Funds appropriated to the Foundation will remain expendable for four years following the appropriation. Of the funds appropriated to the Foundation for research and developmental activities, exclusive of those concerned with national defense, 65 per cent are circumscribed by the bill. Of this 15 per cent must be applied to projects pertaining to national defense and to health and medical sciences; 25 per cent must be apportioned among the states—two fifths in equal shares and the remainder in proportion to their population. The remaining 25 per cent must be expended in the facilities of nonprofit organizations.

Patents which accrue to the Government as a result of Foundation sponsored research will be made available to the public on a nonexclusive royalty-free basis. However, if a contract so stipulates, patent rights may be retained by private organizations, but the Government reserves the right of use on a nonexclusive royalty-free basis. Though in general the Administrator is obligated to publicize widely the results of Government supported research, this duty may become inoperative if the national security demands it.

The Office of Scientific Research and Development and the National Roster of Scientific and Specialized Personnel would be transferred to the Foundation by the bill.

The apparent purpose of S1850 is two-fold. On the one hand, it undertakes to

carry over into peacetime the OSRD type of organization to assist and supplement the research programs of the armed services. On the other hand and in line with the Bush report, it, like the separate Kilgore and Magnuson bills which it supersedes, undertakes to set up a mechanism whereby Congress can appropriate public funds to assist institutions of higher learning in the development of scholarship and fundamental research. The merits of the bill must be judged partly upon the apparent effectiveness of the organization it sets up to accomplish these two purposes. But it must also be judged upon how many extraneous powers and privileges it grants this organization and the federal executive above it. Were it enacted into law, it would establish a very broad enabling act and centralize enormous power over both science and technology in the executive department of the government. The portents of the bill are so serious that they deserve wide discussion. The extended record of hearings make this especially pertinent, for the bill will be found widely at variance with the recommendations made by a majority of scientists in the hearings.

BILL S1777

An alternate proposal for a National Science Foundation composed of 50 members chosen from distinguished men and women in the fields falling within the orbit of the National Academy of Sciences or represented by similar national organizations has been submitted to the Senate in bill S1777, by Senators Willis, Hawkes, Kickenlooper, Wiley, Stanfill, Hart, Smith, and Young.

The President would select all 50 members from nominees presented by the National Academy of Sciences and the national scientific organizations in fields not within the province of the Academy. The Foundation would establish its own rules of organization and fill vacancies among its membership as they arose. The Foundation would not be empowered to make contracts but would have the function of advising Congress of activities worthy of Government support. It would submit an annual report to Congress and foster the maximum dissemination of technical information and scientific discoveries, as well as cooperate with the Secretary of State in furthering international scientific activity.

The members would serve without salary, and the bill proposes to appropriate $100,000 to cover the expenses of organization and the making of its initial report and recommendations. S1777 would preserve the independence of science, in the American tradition, and yet would make financial aid possible.

British Research Bill Now Before Parliament

The creation of an industrial research association for each industry is proposed by the Industrial Research Bill now under consideration in the British House of Lords.

If the bill becomes law most industrial establishments will be required to join associations which will be financed by a tax levy on the proprietors of industry not exceeding one per cent of each contributor's annual revenue. However a method of "contracting out" of such associations is provided for those who would not derive benefit from it; provision also is made for proprietors who wish to appeal for exemption from the terms of the law.

The bill enables the majority interest in any industry to put before the Board of Trade a scheme for operating an association. Once the Board approves the scheme, a poll will be taken of the proprietors in that industry, and, if those in favor represent 75 per cent of the annual revenue in the industry, a research association is formed.

ASA Standardizes Commercial and Household Lamps

A committee which will assure interchangeability of the various types of household and commercial lamps, recently was organized by the American Standards Association.

Present at the first meeting were representatives of user groups, lamp manufacturers, technical and trade associations, and departments of the Federal government. Preston S. Millar (M '13) president of the Electrical Testing Laboratories, New York, N. Y., was appointed chairman of the new committee, and J. W. McNair (A '25) of the ASA, secretary.

As outlined at the first meeting, the committee's work will be concerned with standards of interchangeability of incandescent and gaseous conduction lamps and of the electrical characteristics of operating auxiliaries and with methods of test for such lamps and auxiliaries. It was agreed tentatively that the preliminary work would be carried out through three subcommittees: one on incandescent lamps; one on fluorescent lamps, mercury vapor, and the like; and a third covering methods of testing lamps and auxiliaries. Special attention will be given to the newer types of fluorescent and mercury lamps now coming into wide use.

INDUSTRY.....

Royalty-Free License Offered to Make Bell Equipment

A royalty-free license under Bell System patents to make equipment developed by the Bell Telephone Laboratories for sending telephone conversations over rural electric power lines is being offered to manufacturers of telephone equipment in the United States, the American Telephone and Telegraph Company recently announced.

Known as the rural power line carrier system, the development permits the simultaneous transmission of both telephone conversations and electric power over the same line in rural areas where telephone wires are lacking. The company states that the power line carrier is one of several methods the Bell System is perfecting for use in attaining its objective of extending telephone service to a million additional farm families within the next few years. Carrier development interrupted by the war now has been resumed. Public tests are being conducted near Jonesboro, Ark., with the co-operation of Rural Electrification Administration engineers and jointly with the Alabama Power Company at Selma.

As soon as developments and field trials now under way have progressed sufficiently, other apparatus will be manufactured for the Bell companies by the Western Electric Company and will be available for sale through the Graybar Electric Company.

In a letter to W. C. Henry, president of the United States Independent Telephone Association, announcing this, Keith S. McHugh, vice-president of AT & T, also stated that "at the same time we shall be prepared to extend to manufacturers in this country a royalty-free license to make such power line carrier apparatus in so far as Bell System patents are involved and to sell it for use in the United States for the purpose of extending telephone service directly from a central office of a telephone company to the premises of its rural customers, including service line customers."

Although they expect power line carrier to serve a real purpose in extension of rural service, telephone engineers point out that most farm families will be served by conventional telephone wires. More than 80 per cent of rural residents live within reach of existing telephone pole lines.

RMA Welcomes Amateurs Into Its Fold

With nearly 70,000 licensed radio amateurs in the United States at present and with their numbers expected to increase to between 250,000 and 500,000 in a few years, the Radio Manufacturers Association has given recognition to "ham" activity by forming a new Amateur Radio Activities section with William J. Halligan as chairman.

Purpose of the new section will be to act as a clearing house of information concerning new products needed by amateurs, to establish standards of good engineering practices relative to amateur radio equipment, and to work closely with the American Radio Relay League in the support of amateur radio in legislative and regulatory matters. Subcommittees have been organized to deal with equipment, equipment parts, frequency and power regulation, and promotion and development of amateur radio in foreign lands. W. A. Ready (M '28) president of the National Company, Malden, Mass., is a subcommittee head.

The last-named subcommittee has the

task of encouraging greater recognition of amateur operation among foreign governments, some of which have taken active measures against amateurs. Pointing out that amateur frequencies are established by international agreement, Mr. Halligau ascribed most of the losses which amateurs have sustained to the antipathetic attitude of other governments. The RMA hopes to persuade foreign manufacturing associations to co-operate with their national amateur organizations. Mr. Halligan declared that amateur radio furnished a backlog of skilled personnel to the radio industry and listed as the outgrowth of amateur work the discovery of the practical value of short waves, the introduction of low-loss coils, the neutrodyne, the single control superheterodyne, the single signal receiver with crystal filter, the noise limiter, and the first application of 100 per cent modulation.

Recent Progress in Silicones Reported by Two Companies

A special program for the development of laminates from silicone resin and fiber-glass fabric base for use in applications where resistance to high temperature is necessary is in progress at the Formica Insulation Company, Cincinnati, Ohio, under the sponsorship of the Navy Department Bureau of Ships.

An essentially satisfactory laminated sheet material has been produced, the company discloses, and is in process of being tested. It is expected to provide electrical insulation material having properties of extremely high resistance to temperature and able to withstand heat far in excess of materials used during the war.

A silicone glass laminate developed by the General Electric Company, Schenectady, N. Y., also has reached the testing stage. This laminate has survived a week-long test at 250 degrees which surpasses the resistance of any similar product. According to the company's announcement, ordinary solder will melt before this new material, constructed of layers of glass cloth treated with a silicone resin and subjected to heat and pressure, will break down. The weight of the material is about the same as magnesium and the company anticipates using it in such standard equipment as motors, circuit breakers, induction heaters, and high frequency oscillators. Other possible uses are as handles for arc welding electrodes and for indestructible insulating parts of devices subject to fire hazards.

International Lighting Exposition in Chicago

Manufacturers of lamp and lighting equipment and of products related to lighting will display the most recent developments in that field at the International Lighting Exposition to be held April 25–30, 1946, in the Stevens Hotel, Chicago, Ill.

A series of conferences will be held for architects, electrical contractors, wholesalers, industrial executives, illumination engineers, school authorities, public officials, industrial, and business executives. Some of the problems discussed will be: how light can be used to increase sales; how the industrial executive can increase production, reduce accidents, and conserve eyesight; how improved lighting in schools betters educational results; and how the contractor or utility representative can introduce newest developments to customers. An industry round table discussion will be featured on the subject "What New Methods and Materials for Technical and Sales Training Are or Will Be Available."

Industrial exhibits presenting the latest trends in lighting for industry, business, stores, farms, play areas, schools, airports, and streets have been arranged. In addition an educational exhibit is being sponsored by the Illuminating Engineering Society.

Among the new lighting developments to be introduced to the public are: completely redesigned fluorescent lighting units of porcelain enamel, steel, and plastics; new types of units including cove and built-in lighting; prismatic glass light control equipment; explosionproof aviation, street, subway, and viaduct lighting equipment; sports, service station, and other types of flood lighting; germicidal lamps; and new desk lamps.

Illinois Institute Laboratory Initiates Service for Industry

The facilities of the laboratory for precision measurement of electrical and magnetic quantities, which was established at the Illinois Institute of Technology in 1945 (*EE, Apr '45, p 169*) through a gift of the Ohmite Manufacturing Company, now are available to sponsoring organizations, according to an announcement by Doctor J. E. Hobson (M '41) director of the Institute's Armour Research Foundation.

Designed to provide services to industries within the Chicago area, the laboratory also will be used for graduate study and in electrical standardizing work for the various departments of the school. Although some equipment for the precision measurement work is not yet available, the laboratory is equipped for the following activities: calibration of standard cells, shunts, standard resistances, capacitors, inductors, d-c and a-c ammeters, voltmeters, wattmeters, and watt-hour meters; conductivity measurements and insulation resistance measurements; determination of the properties of magnetic materials; measurements of power factor and dielectric constant of liquid dielectrics; oscillographic work; and radio and radio frequency measurements, including frequency checks and field strength determinations up to 20 megacycles, determination of Q and antenna impedance.

According to L. W. Matsch (M '41), codirector of the undertaking, the activities in the Ohmite Laboratory are expected to include high-voltage measurements up to 100,000 volts by the middle of 1946. The scope of the audio and radio frequency work also will be increased.

Baltimore–Norfolk Boats Install Radar Equipment

First major marine installation of radar equipment as a navigational aid on commercial passenger-carrying vessels has been made by the Westinghouse Electric Corporation on the Old Bay Line's night boats making the 185-mile run between Baltimore and Norfolk.

The type of installation made for the operational test runs provides a continuous picture of ship traffic and shore line conditions for a range of from 100 yards to 32 miles of the ship at all times. Water surfaces will be dark on the 7-inch viewing area of the cathode ray tube indicator, while any obstruction will show as a bright fluorescent pattern. Ships will appear graphically and shore lines as on a map. For navigation in narrow channels, approaching piers, or near other craft, the viewing area gives greater detail, duplicating a circle only four miles in diameter with the ship in the center.

The antenna is mounted under a large mushroom-shaped plastic dome atop a $5\frac{1}{2}$-foot pedestal on the wheelhouse roof with the modulator, preamplifier, and other radio frequency components in the weatherproof base of the pedestal. The receiver-indicator console, a cabinet 2 feet square and 48 inches high, is located on the bridge. Power for operation of the equipment is provided through a below-decks rotary converter from the ship's main d-c power supply.

Flight Tests Verify Stratovision Operation

Tests of "Stratovision," a proposed system of nation-wide television and frequency-modulation broadcasting from airplanes operating in the stratosphere (*EE, Sept '45, p 346*), show that usable signals can be transmitted over a distance of 240 airline miles from an altitude of 25,000 feet using only 250 watts of power, according to a recent announcement of the Westinghouse Electric Corporation, codeveloper of the system with The Glenn L. Martin Company.

Transmission characteristics of both television and frequency modulation were studied during the test flights. Television work centered around the problem of "ghosting"—out-of-register viewing which occurs when a receiver picks up a signal by two different wave paths. Frequency modulation data were obtained on transmission in the new band above 100 megacycles by a constant recording of field strength of a carrier wave, both modulated and unmodulated.

The tests, which are being checked by Federal Communications Commission

monitoring stations, are made with a refitted twin-engine medium bomber and a ground station located at the Baltimore, Md., plant of the Westinghouse corporation.

RCA Inspection Device Detects Metal Particles

An industrial inspection device with a high degree of flexibility of application which will detect metal particles of any kind present in nonmetallic industrial materials recently was displayed by the RCA Victor Division of the Radio Corporation of America at the 20th Chemical Exposition in New York.

The versatile completely self-contained unit is 43 inches long by 15 inches wide with an over-all height of 20 inches plus the height of the inspection aperture, which varies from 4 to 12 inches. In operation, materials passing through the aperture by means of a conveyer belt or a chute, are screened by a high-frequency electromagnetic field, generated by coils embedded in plastic panels above and below the aperture. An electronic oscillator supplies high-frequency power to the coils, and the reaction set up by metal is detected and amplified by an electron tube amplifier. This amplified reaction can be used to light a warning lamp, ring a bell, stop a continuous process, mark the contaminated object, or deflect it into a special channel for rejects.

Unlike magnetic detectors, the device will expose any kind of metal alloy, including iron, copper, brass, lead, aluminum, stainless steel, and others. It can be adjusted so that it will detect the required size of particle for each installation. The operator need check the adjustment of only one simple control approximately once a day.

Chicago Exposition Postponed. Because of the uncertainty about production and deliveries among the nation's manufacturers, the Products of Tomorrow Exposition scheduled to open April 27 in Chicago has been postponed indefinitely, according to Marcus W. Hinson, general manager of the exposition. Manufacturers who intended to display their postwar products now consider it inadvisable to participate in public exhibits until they are more certain of their future capacity for delivery, Mr. Hinson said. Mr. Hinson revealed that industrialists in India, Britain, Russia, Holland, China, and South America have indicated their intention to take part in the exposition which may be held in the fall of 1946 or early in 1947.

Westinghouse Again Awards Fellowships

Resumption of its fellowships for young scientists to work on pure scientific research of their own choosing has been announced by the Westinghouse Electric Corporation.

Appointment of three young men for a year's work in the company's research laboratories will be made in May, and work on the various projects will be started by October 1. Applications must be received at the Westinghouse laboratories by April 15. Under the fellowship plan, young scientists having training equivalent to that represented by a doctor's degree from a recognized university are selected for one year's work. They may be reappointed for a second year if mutually desirable. The fellowship has a value of $3,000 a year.

The board of review making the appointments is composed of Doctor L. W. Chubb (F '21), director of the Westinghouse laboratories, Doctors C. R. Hanna (M '30), J. A. Hutcheson (M '44), and Joseph Slepian (F '27), all associate directors, and the manager of the department in which each applicant's project will be carried out.

Jewett Fellowships Awarded

Award of five Frank B. Jewett fellowships for postdoctorate research in the physical sciences has been announced by the American Telephone and Telegraph Company which founded the grants in 1944 upon Mr. Jewett's retirement as vice-president of the company.

The recipients, three of whom are chemists and two physicists, are Doctor Martin G. Ettlinger of Harvard University and Austin, Tex.; Doctor Edward W. Fager of Manhattan Project and New York; Doctor Bernard Goodman of the University of Pennsylvania and Philadelphia; Doctor Shuichi Kusaka of Northampton, Mass.; and Doctor Robert L. Scott of Manhattan Project and Santa Ana, Calif. All have been engaged in war research with the exception of Doctor Kusaka, a native of Osaka, Japan, who was teaching at Smith College until he resigned to enlist in the Army and obtain United States citizenship.

The awards carry an annual stipend of $3,000 to the holder and $1,500 to the institution at which the recipient elects to do research. Principal criteria used in selecting the recipients are: demonstrated research ability, the fundamental importance of the problem to be attacked, and the likelihood of his growth as a scientist.

Anniversary of Telephone. The 70th anniversary of the telephone, first patented by Alexander Graham Bell on March 7, 1876, was observed this year. It was not until May 1877 that the first telephones were put into use commercially but 68 years later, by the end of 1945, there were 22,445,500 Bell System telephones in service, plus more than 5,400,000 operated by 6,000 independent companies. Future plans for the telephone include nation-wide dialing by long-distance operators, devices for taking a message if there is no one to answer the telephone, and extension of the use of two-way voice communication by radiotelephone between motor vehicles.

Chileans Ask Manufacturers' Literature. The Universidad Tècnica Federico Santa Maria of Valparaiso, Chile, is interested in receiving catalogs, pamphlets, and prospectuses of the leading manufacturers in the United States handling machinery and technical equipment, according to the United States Consul in Valparaiso. The university has material from European manufacturers but little or none from the United States. Were the material available students would have the opportunity of studying United States methods and machinery and of becoming acquainted with its products. The university, it is noted, is the leading technical institution of Chile.

Radar Distance Indicators. A new radar navigation system which gives the pilot constant indication of his position has been developed by the United States Army Air Forces together with the General Electric Company. Under this system radar equipment in the airplane sends out radio waves of very high frequency which speed at 186,000 miles a second to a centrally located radio beacon in the area which the airplane is approaching. The beams are reflected back to the radar equipment, giving a continuous reading of the distance between the beacon and the airplane. The combination of this distance-measurement system with a direction-finding system would give the pilot all the information necessary for a complete navigation system, as he could continuously fix both his exact distance from and direction to a given point.

To Convert RCA Television Receivers. Prewar RCA Victor Division television receivers will be converted to receive programs on the new frequency channels allocated by the Federal Communications Commission, the RCA Service Company, Inc., has announced. All owners of RCA Victor sets have been notified that the company will incorporate revised circuits and reinstall the set in the owner's home at a charge of $30. The new allocations have shifted the frequencies of existing stations both by changing the frequency bands for given channel designations and by moving stations to new channels. RCA Victor receivers now providing for reception on channels 1 to 5 inclusive will be changed to receive programs on channels 2 to 6 inclusive.

Philco Has Portable Television Studio. A new portable 35-pound television camera and lightweight "suitcase-type" control equipment have been developed, the Philco Television Engineering Laboratories announced recently. Several of the lightweight cameras can be operated from a single portable master control unit. The control unit may be 500 feet from the cameras, which can be arranged to pick up various angles of the event being recorded.

Effectiveness of the camera was tested at the University of Pennsylvania football games in the autumn of 1945. Pictures of better definition and detail were obtained by utilizing latest types of camera tubes and new electronic circuits for auxiliary units.

Transformers for Electronic Heating. New lightweight transformers in sizes between 2 and 50 kva single phase and 2 and 100 kva three phase have been developed by the Westinghouse Electric Corporation for electronic heating purposes. The transformers are air cooled and can be insulated for test voltages as high as 20,000 volts, which is nearly double the maximum of previous air-cooled transformers. One representative unit using type-C Hipersil core, high-temperature insulation, and air-blast cooling weighed 275 pounds. The same unit built with class A insulation and self-cooled, would have been 1,600 pounds.

Kellogg and Philco Work Jointly. An exclusive distributing agreement by which the Kellogg Switchboard and Supply Company, Chicago, Ill., will furnish and install frequency modulation mobile radiotelephone equipment manufactured by the Philco Corporation has been signed by the two companies. Mobile radiotelephone units under the agreement will be designed primarily for use in private automobiles, trucks, busses, taxicabs, yachts, and other vehicles and will incorporate the latest electronic developments.

Electric Truck Survey. A 350 per cent increase during the past 21 years in the number of battery-powered industrial trucks in use in the United States is revealed in a survey, results of which were announced recently by the Electric Industrial Truck Association, Chicago, Ill. The survey shows 39,782 such trucks in use at the end of 1944 as compared with 11,350 in 1923. It also revealed that use of electric trucks in material-handling systems showed consistent growth of approximately 65 per cent from 1923 to 1931 and more than doubled in the period from 1931 to 1944 although, during the war years, production was curtailed by demands of the war program.

LIBRARY

H. W. Craver Retires From ESL Directorship

Doctor Harrison W. Craver, formerly director and secretary of the Engineering Societies Library, has retired after nearly 29 years of service. He will continue to serve in an advisory capacity, however, with the title of consulting librarian.

Doctor Craver began his association with the library in 1917 and under his leadership the library has extended its facilities for reference and its opportunities for research to a very great number of persons throughout the United States and Canada. In recognition of his long career a statement of appreciation has been prepared to be incorporated in the library board minutes and a copy presented to Doctor Craver.

Ralph H. Phelps, formerly assistant director, has been appointed acting director.

Engineering Library Receives Barstow Bequest

A legacy of $10,000, the last of many liberal gifts to the Engineering Societies Library by the late William S. Barstow (F '12), recently has been received from his estate. The income from this endowment now supplies about one fifth of the library revenue. A similar bequest of $10,000 also was made to AIEE.

The prosperity of the library was a major interest to William Barstow, who died in 1943 (*EE, Feb '43, p 76*). He was a member of the Library Board from 1931 to 1942 and of the executive committee of the Board from 1934 to 1942. Between 1935 and 1938 he donated $7,500 to cover the cost of binding and repairing the rare books in the library. Most of these were books from the Latimer Clark collection which was given to the library through the AIEE by Schuyler Skaats Wheeler. In 1940 William Barstow gave $500 for the extension of the services of the library.

Future Meetings of Other Societies

American Public Power Association. Annual meeting, May 9–10, 1946, Memphis, Tenn.

American Chemical Society. National Chemical Exposition. September 10–14, 1946, Chicago, Ill.

American Society for Testing Materials. Annual meeting. June 24–28, 1946, Buffalo, N. Y.

American Society of Mechanical Engineers. Annual meeting, June 17–20, 1946, Detroit, Mich.

American Society of Tool Engineers. Exposition. April 8–12, 1946, Cleveland, Ohio.

Canadian Electrical Association. Annual meeting. June 26–28, 1946, Banff, Alberta, Canada.

Edison Electric Institute. June 3–5, 1946, New York, N. Y.

Electrochemical Society. Spring meeting. April 10–13, 1946, Birmingham, Ala.

Great Lakes Power Club. Spring meeting. May 24, 1946, Chicago, Ill.

Illuminating Engineering Society. National convention. September 18–21, 1946. Quebec, Quebec, Canada.

Instrument Society of America. Exhibit and conference. September 16–20, 1946, Pittsburgh, Pa.

National Association of Corrosion Engineers. Annual meeting and convention. May 7–9, 1946, Kansas City, Mo.

National Electrical Manufacturers Association. First International Lighting Exposition April 25–30, 1946, Chicago, Ill. June 17–19, 1946, Hot Springs, Va.

National Fire Protection Association. June 3–6, 1946, Boston, Mass.

Pennsylvania Electric Association. Spring meeting. May 28–29, 1946, Harrisburg, Pa.

Radio Manufacturers Association. Trade show. May 13–16, 1946. Chicago, Ill.

Society of Plastics Industry. First national plastics exposition. April 22–27, 1946, New York, N. Y.

OTHER SOCIETIES

Westinghouse Centennial Commemorated by ASME

With "George Westinghouse—the Man and the Engineer," as their theme, prominent speakers recently addressed a dinner at the Engineers Club, New York, N. Y., sponsored by the American Society of Mechanical Engineers to honor the centennial of the birth of George Westinghouse, who was an ASME president.

D. Robert Yarnall of Philadelphia, Pa., president of the ASME, presided, and Dean Dexter S. Kimball of Ithaca, N. Y., a past president, was toastmaster. Other speakers included Albert N. Williams of Pittsburgh, Pa., vice-chairman of the board of the Westinghouse Air Brake Company; Dean Samuel W. Dudley of the School of Engineering, Yale University, New Haven, Conn.; and Frank D. Newbury (F '21) vice-president of the Westinghouse Electric Corporation, Pittsburgh.

Speaking on "Westinghouse—the Individualist," Mr. Newbury urged recognition of individual initiative, co-operation of employer and worker, and business leadership as three essentials of a sound national economy. He charged that "co-operation between employers and employees and between businessmen and the public has been systematically undermined by government and by labor-union propaganda."

He decried the comtemporary emphasis on equalizing purchasing power as against equalizing earning power and the fact that "The people have been taught that profits are a social evil, that in some way—never explained—everyone could enjoy a life of abundance if only industry were not strangled by the profit motive." Savings out of profits enable industry to increase its productivity and thereby increase real wages, Mr. Newbury reminded his hearers.

Defending business leadership, Mr. Newbury stated that American business has no reason to apologize for its record. "Industrial leaders—at their worst of self-seeking and abuse of power—were producing, were developing the country, were increasing jobs and incomes. They could advance their own interests most by increasing production. They couldn't help being on the side of production," he continued.

"But political leaders and labor leaders—at their best—can only help industry produce. They do not directly contribute to the production of wealth. Their major purpose is to redistribute wealth. At their worst—and we have seen some of it during the past few months—political and labor leaders get in the way of production, jobs, and better living," he said.

Stating that planned economy is fallacious, because growth cannot be planned, Mr. Newbury concluded his speech: "The development of an idea, an invention, an industry, is unpredictable. Growth or stagnation is in the hands of our leaders. George Westinghouse, engineer, organizer, individualist, would surely approve of that."

Mr. Williams' topic was "Westinghouse's Position in the History of Transportation." In praising the accomplishments of American railroads, which in 1943 handled double the ton-miles volume of freight with 570,000 fewer employees and 650,000 fewer cars than in 1917, he gave credit to George Westinghouse. Such accomplishments measure the capability of the air brake as well as the engineering practice established by its inventer, he said.

Mr. Williams also reviewed George Westinghouse's development of the friction draft gear to save wear and tear on rolling stock and its cargo and his innovations in railroad switching and signaling. Out of his basic signal system came centralized traffic control, which found its proving ground in World War II.

"Westinghouse—the Man" was discussed by Dean Dudley, who saw in the inventer "a giant in physique, endurance, intellect, personality, and spirit." Westinghouse was a pioneer in consideration of the welfare of his employees, Dean Dudley pointed out. He was the first employer of his day to inaugurate the Saturday half holiday. He developed the use of labor-saving devices in his factories, improved working and housing conditions for his workers, and provided pensions for their old age.

Gwilym A. Price, president of Westinghouse corporation, made the first announcement of his firm's centennial program, in Pittsburgh May 16, 17, and 18. It will consist of a science and engineering forum, with such noted participants as Doctor Karl T. Compton (A '31) president of Massachusetts Institute of Technology; Doctor Vannevar Bush (F '24) director of Office of Scientific Research and Development; Doctor Selman A. Waksman, discoverer of the new drug, streptomycin; Doctor Enrico Fermi of the University of Chicago; Major General Roger B. Colton of the Army's radar and electronics program; Doctor Frank B. Jewett (F '12) president of the National Academy of Sciences; Charles Kettering (F '14) of General Motors Corporation, and other leaders in the fields of science, engineering, and industry.

National Safety Council Opens Drive for Funds From Public

For the first time in its 33-year history the National Safety Council has launched a nation-wide appeal for funds to support its far-reaching accident prevention work. The Council, which was organized for public safety in 1913, and has existed hitherto with the financial backing of a small group of industrial concerns and individual contributors, has been credited with saving at least 330,000 lives that might have been lost had the accident rate continued at the 1913 level.

By gaining the financial support of the public at large, the Council hopes also to obtain more active participation by the general public in efforts to control the number of accidents in the country. It plans to make the Green Cross, official insignia of the drive, an omnipresent reminder against possible carelessness.

In announcing the campaign, Ned H. Dearborn, president of the Council, compared the number of deaths and injuries from accidents and from World War II. "During the war, deaths and injuries from accidents on the home front exceeded battle casualties among the American forces," he declared. "Our losses from enemy action were 261,608 killed, and 651,911 injured. Home front accidents of all types during this period claimed 355,000 lives and brought injuries to 36,000,000 persons, no less than 1,250,000 of these injuries being of a permanent nature."

Mr. Dearborn also noted that there were 96,000 Americans killed last year in all types of accidents—equivalent to the annihilation of six full infantry divisions. At least 10,300,000 persons were injured in all accidents in 1945 alone—a total approximating the peak war strength of the armed forces of the United States.

ASTM Studies Electrical Materials

A study group of the American Society for Testing Materials recently was set up to plan for the enlarged scope of the ASTM committee B-1 on materials for electrical conductors. The committee's work now will include all of the common materials used for electrical conductors rather than being limited to copper and copper-alloy wires.

As a result of the reports of task groups appointed for the purpose of recommending changes in parts of present specifications, consideration is being given to preparing methods of tests for determining the actual areas of cross section of finished stranded conductors, either on a weight or resistivity basis. The conversion of specifications B 193–45 T from a resistivity basis to a conductivity basis also is being considered and a task group has been appointed to review specifications B 9–39 for bronze trolley wire and B 47–39 for copper trolley wire in regard to necessary revisions.

The subcommittee on insulating tape of committee D-11 on rubber and rubber-like materials has recommended the withdrawal of the emergency alternate provisions applied to the specifications for friction tape for general use for electrical purposes (D 69–38) and for rubber insulating tape (D 119–38). Both of these standard specifications will be reverted to the tentative status and revised to include a number of the former emergency provisions. Consideration is being given to new specifications for thermoplastic jackets and a revision and clarification of the ozone test in the methods of testing rubber insulated wire and cable (D 470) has been recommended. In addition the method of heat aging of vulcanized or synthetic rubber by test tube method (D 865) has been modified to lower the test temperature from −25 degrees centigrade to −35 degrees centigrade. A steering committee also will be appointed which will review certain emergency alternate provisions applying to specifications for insulated wire and cable as well as study and co-ordinate the various ASTM specifications for rubber insulation for wire and cable.

A study of problems connected with cathode emissivity has been undertaken by a subcommittee of the committee on electrical heating, electrical resistance, and electric-furnace alloys. The subcommittee is composed of technical representatives of the various receiving tube companies, other interested industrial organizations, colleges, and Government laboratories.

At present four lines of investigation are being followed. A metallurgical group and a chemical group have been formed, and with the co-operation of nine companies the testing of various cathode materials under standard tube conditions is being co-ordinated by another group. A fourth group is analyzing all data received as well as the actual production experience in the participating companies.

It is the aim of the subcommittee to find a method for testing cathode base metal emissivity which will eliminate the large number of variables occurring when regular tube tests are run. As a first step a standard diode structure is being tested. By picking materials with extremes of results it is expected that information will be obtained through chemical or metallurgical methods which will permit accurate forecasting of results.

1946 ASHVE Guide Available. The 24th edition of the "Heating Ventilating Air Conditioning Guide" published by the American Society of Heating and Ventilating Engineers is currently available. It contains 51 technical chapters grouped under general section headings such as "Heating and Cooling Loads," "Heating Systems and Equipment," and "Air Conditioning," plus a membership roll of the Society and 376 pages of equipment data. The latter section is complete with a cross index to aid in finding any desired product. The Guide, 6 by 9 inches in size and bound in blue cloth stamped with gold, may be purchased from the society, 51 Madison Avenue, New York, N. Y., at a cost of $6.

Resistance Welding Publication. "Recommended Practices for Resistance Welding," a compilation of recommended practices for the spot and seam welding of low carbon, stainless, and hardenable steels, nickel, monel, and iconel; the projection welding of low carbon and stainless steels; flash-butt welding low and medium forging strength steels; and standard methods for

testing resistance welds, now is available from the American Welding Society, 33 West 39th Street, New York 18, N. Y. Each recommended practice comprises a table of machine settings for current, voltage, time, pressure, and other factors which will produce welds of specified strength in various thicknesses of materials. Tests for tensile properties, shear strength, impact strength, fatigue properties, and hardness are included as well as a complete description of the test specimens, the equipment to be used, and the procedure to be followed, and a section on control of weld quality by statistical methods. Copies are 50 cents each.

Welding Prizes Increased. Announcement has been made by the American Welding Society that the amount of the prizes it awards annually for the best technical papers on resistance welding has been increased substantially by the donor, the Resistance Welder Manufacturers Association, so that the awards now total $2,000. The prizes will be awarded as follows:

$730, $500, *and* $200—For the best, second best, and third best paper respectively, emanating from an industrial source, consulting engineer, or the like, in which the major portion of the subject matter is concerned specifically with resistance welding.

$300, $200—For the best paper and second best paper emanating from a university source—that is, either from an instructor, student, or research fellow—which is the greatest original contribution to the advancement and use of resistance welding.

The contest, which opened August 1, 1945, and will close July 31, 1946, is open to anyone from the United States, its possessions, and Canada. A member of the American Welding Society in any part of the world is eligible.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication has in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Inclusive Professional Engineering Society

To the Editor:

The writer read with considerable interest the summary of the annual meeting of the Engineers Council for Professional Development as reported in the December issue of *Electrical Engineering*, pages 461–2. The work being carried on by that organization would appear to be well considered and executed.

The writer is somewhat puzzled by one important omission in the discussions regarding uniform membership grades and professional attributes. The professional engineering laws now in effect in most states would seem to bear directly on these matters and particularly the professional attributes.

The subjects of professional recognition and of legal status are related almost inseparably. The professional engineering laws offer a suitable means of specifying and instituting legal minimum qualifications for engineers and for putting a stop to the present misuse and abuse of the title "engineer" by so many unqualified persons. It is useless to argue that there may be better methods of providing minimum standards than the professional engineering laws. Many of those laws have been in effect for a considerable period of years and the process itself is becoming thoroughly ingrained. It is difficult to conceive any other means by which legal status can be conferred. It is much too late to contemplate turning such authority over to the technical societies. Furthermore, while the great technical societies centered at 33 West 39th Street, New York, have high standards, there are a multitude of other so-called "engineering" societies and it would be a legal nightmare to sort them out on a basis of responsibility.

The ECPD recommendations on uniform membership grades seem quite reasonable. The qualifications recommended for Member are strikingly similar to those required in most states for a Professional Engineer's License. Certainly any institution of uniform membership grades would require a transition period. This well might be accomplished first by recognizing a Professional Engineer's License as qualifying an Associate or nonmember for the grade of Member and then at some suitable future date making such license mandatory for the grade. There would seem no point to the Institute's conducting separate qualifying examination when almost all of the states and all of the Canadian Provinces already have in effect licensing laws with almost identical requirements to those suggested by ECPD.

One disturbing item in the report is the indication that for 12 years the ECPD and the major technical societies have discussed uniform membership grades without being able to come to any decision. The same fate seems to have overtaken many of the important professional activities the committe normally would be expected to deal with. This situation lends emphasis to the proposal for an over-all professional engineering society as first outlined by C. A. Powel and later given concrete expression by James F. Fairman in their respective articles in *Electrical Engineering* (*January 1945, pages 14–16 and June 1945, pages 220–3*).

The Founder Societies and their fellow major technical societies have accomplished an outstanding success in their respective technical fields. Unfortunately the characteristics which have carried them to these successes have kept them from functioning effectively on professional activities and co-ordinating with one another. It is all very well for the ECPD to debate, discuss, and submit propositions and proposals to the societies who then individually sit down consider, discuss, and perhaps reject so that the matter goes back to ECPD for further study and so on.

The only alternative to an over-all professional society would seem to be some organization or council of the major technical societies constituted of representatives with power to act as well as talk. The fate of the American Engineering Council does not augur very well for the success of such an enterprise. It was after thorough consideration of these facts that the writer first secured a Professional Engineer's License and then joined the National Society of Professional Engineers. That group is as yet rather weak numerically but it seems to have the major attributes required for a successful professional society—it can and will be built into the powerful over-all professional engineering society that is needed so badly. In Ohio that thought seems to be gathering strength among engineers.

Please understand that the writer has no intention of belittling ECPD or the AIEE. If ECPD carried out no other function than that of accrediting engineering schools its existence would be justified. The writer has been affiliated with AIEE since 1930 and fully appreciates its leading position as a technical society. The failure of the technical societies to cope with professional developments must be recognized. It is suggested that AIEE propose a joint committee of major technical societies to look into the matter of an over-all professional society and issue a joint report. Perhaps this matter could be referred to ECPD but in any case a time limit should be set and a *definite report* demanded. In any such committee the only functioning responsible professional society, NSPE, must be given adequate consideration. Thirteen years have gone into making NSPE a sound and going organization and they should not be thrown away lightly unless there is a very good reason. It should be kept in mind that the vast majority of NSPE members are also members of one or more of the technical societies and that for the forthcoming year one man, James Fairman, will be a vice-president of both AIEE and NSPE. In short it is time to call a halt to the endless round of talk about forming a suitable professional organization and resort to some concrete action.

JAMES P. MUNROE (A'33)

(Dayton Rubber Manufacturing Company, Dayton Ohio)

Division of Load With Transformers Operating in Parallel

To the Editor:

When transformers are to be operated in parallel to supply continuous heavy loads it is important to determine the division of load between each unit. This is particularly true where the transformers are connected together at the same location with a minimum run of secondary mains to the point of supply.

If two transformers having the same ratio of transformation are connected in parallel to a common load the total secondary current is divided between them approximately in inverse proportion to the impedance ratings. The inverse impedance can be expressed as

$$Y = \frac{P}{Z} = \frac{P}{RW + jLW}$$

Y = admittance
P = size of transformer in kilovolt-amperes
RW = secondary winding resistance
LW = secondary winding reactance
Z = per cent impedance

The impedance rating usually can be obtained from the manufacturer's name plate on the transformer. The values are expressed in per cent of rated secondary voltage and it will be found that they vary considerably for the same manufacturer and same type of transformer. Considerable variation also will be found for the same type of transformer made by different manufacturers.

To illustrate the effect of different impedance ratings on the load division in two transformers, we will assume that a load of 100 kva is to be supplied by two 50-kva transformers connected in parallel. Transformer A has an impedance rating of 2.3 per cent and transformer B has a rating of 3 per cent.

The admittances will be

For transformer A $\quad \frac{50}{2.3} = 21.74$

For transformer B $\quad \frac{50}{3} = 16.66$

The division of the total load of 100 kva then is

For transformer A

$$\text{kva} = \frac{Y_a \times \text{kva}_T}{Y_a + Y_b} = \frac{21.74 \times 100}{38.4} = 56.61 \text{ approximately}$$

Y_a = admittance of transformer A
Y_b = admittance of transformer B
kva_T = total load kilovolt-amperes

For transformer B

$$\text{kva} = \frac{16.66 \times 100}{38.4} = 43.39 \text{ approximately}$$

Under these conditions transformer A is loaded 113.2 per cent of rated capacity and transformer B is loaded to 86.7 per cent of rated capacity.

To illustrate another application, let it be assumed that two transformers of like ratio are to be connected in parallel to supply a total load of 25 kva. Transformer A is a 15 kva with an impedance rating of 3 per cent and transformer B is a 10 kva with an impedance rating of 2.1 per cent.

The admittance will be

For transformer A $\quad \frac{15}{3} = 5$

For transformer B $\quad \frac{10}{2.1} = 4.76$

The division of total load of 25 kva then is

For transformer A $\quad \text{kva} = \frac{5 \times 25}{9.76} = 12.8$ approximately

For transformer B $\quad \text{kva} = \frac{4.76 \times 25}{9.76} = 12.19$ approximately

In this case transformer A is loaded only 82 per cent and transformer B, which is the smaller of the two, is loaded at 121.9 per cent of rated capacity.

It is felt that this method is the simplest way to obtain values for load division of transformers operated in parallel at the same location and is accurate enough for all practical purposes. This method will be found useful to the plant engineer who may have a large single phase industrial load to handle with a wide selection of idle transformers of different makes and designs to select from.

JAMES H. F. WHITE (A '45)
(District engineer, Westchester Lighting Company Pleasantville, N. Y.)

NEW BOOKS . . .

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

ASTM STANDARDS ON ELECTRICAL INSULATING MATERIALS. Prepared by ASTM committee D-9 on electrical insulating materials; Specifications, Methods of Testing; October 1945. American Society for Testing Materials, 260 South Broad Street, Philadelphia, Pa. 545 pages, illustrated, 9 by 6 inches, paper, $3.25. The specifications and test methods covering electrical insulating materials are brought together, with several reports on the significance of the tests and other subjects of interest.

DEMOCRATIC ADMINISTRATION. By O. Tead. Association Press, 347 Madison Avenue, New York, N. Y., 1945. 78 pages, 9½ by 6 inches, cloth, $1.25. In this small volume, part I, entitled "Creative Management," considers the nature and aims of organizations for social, civic, and character-building purposes in order to establish effective administrative procedures. Part II, "Democracy in Administration," develops in a more general way the thesis that "the process of determining purpose, policy, and method advisedly is seen as shared, and the process of oversight and direction is seen as unified and single."

ELECTRON OPTICS AND THE ELECTRON MICROSCOPE. By V. K. Zworykin, G. A. Morton, E. G. Ramberg, J. Hillier, and A. W. Vance. John Wiley and Sons, Inc., New York, N. Y.; Chapman and Hall, London, England, 1945. 766 pages, illustrated, 8½ by 5½ inches, cloth, $10. Part I of this treatise offers a comprehensive description of the various types of electron microscopes, a nonmathematical discussion of electron optical theories on which they are based, and a practical guide for their effective operation. Part II contains a thorough coverage of the mathematical theory. Important topics considered include: the determination of potential distribution; electron trajectory tracing; magnetic fields and electron motion; electron lenses, their aberrations and corrective measures; and image formation in the electron microscope. A list of references accompanies each chapter.

ELECTRONICS FOR ENGINEERS. Edited by J. Markus and V. Zeluff. McGraw-Hill Book Company, Inc., New York, N. Y., and London, England, 1945. 390 pages, illustrated, 11 by 8½ inches, cloth, $6. The articles, charts, and graphs presented in this volume have been selected from those that have appeared in *Electronics* because constant demand has shown their permanent reference value. Consultation has been made easy by collecting the 142 articles in 27 chapters by subject. Designers and builders will find the data useful and convenient.

FLUOROCHEMISTRY. By J. De Ment. Chemical Publishing Company, Brooklyn, N. Y., 1945. 796 pages, illustrated, 9½ by 6 inches, cloth, $4.50. The basic concepts of fluorochemistry are defined with description of its characteristic phenomena. The applications of fluorescence, luminescence, and radiation in science, medicine, and industry are explained in simple language. The book describes methods for the preparation of the various luminescent organic substances, dyestuffs and coloring matters, and ultraviolet-emitting inorganic and organic substances and gives qualitative and quantitative tests for their identification. Experimental research results are presented. There is an extensive bibliography and a glossary of terms and notations.

NORMALISATION. By J. Mally, preface by P Salmon. Dunod, Paris, France, 1946. 472 pages, 9¾ by 6½ inches, paper, 375 francs. In this interesting study of standardization, attention is given especially to the legal aspects of the subject and on its effects on the general economy of a country. The principles and methods of standardization and the applications of standards are reviewed in the first section. The second deals with standardization in France. Standardization in Germany and England is reviewed briefly, as is international standardization.

PAMPHLETS . . .

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

Minimum Specifications for Wirebound Boxes for Industrial Domestic Shipments. The Wirebound Box Manufacturers Association, 43 East Ohio Street, Chicago 11, Ill.

A Program for Community Relations. By Walter Geist. National Electrical Manufacturers Association, 155 East 44 Street, New York 17, N. Y., 14 pages. Copies may be secured at cost.

How to Rebuild Skilled Labor Force for Peace. Apprentice-Training Service, United States Department of Labor, 1778 Pennsylvania Avenue, N. W., Washington 25, D. C., 4 pages.

Electronics Digest. Published quarterly by the Westinghouse Electric Corporation, Box 168, Pittsburgh 30, Pa.

TRANSACTIONS SECTION

Preprint of Corresponding Pages From the Current Annual AIEE Transactions Volume

Applications of Thin Permalloy Tape in Wide-Band Telephone and Pulse Transformers

A. G. GANZ
MEMBER AIEE

THE development of thin permalloy tape and its use in cores have resulted from the increasing need for efficient magnetic structures at high frequencies. For some time for example, the trend in the telephone plant has been to the use of higher frequencies in the longer distance toll circuits. The reason is that these permit the simultaneous transmission of a larger number of telephone conversations over a single conducting circuit. The coaxial transmission system developed before the outbreak of the war, operates over the range of about 64 to 3,200 kilocycles and required transformers for repeater amplifiers and terminals capable of passing this wide band efficiently. Eddy current effects at these frequencies preclude the use in such transformers of magnetic material in conventional thicknesses.

With the advent of radar pulse transformers were needed urgently to transmit high power pulses. The latter are in the order of a microsecond in length and square-shaped with very steep sides. Fourier analysis of the pulses reveals large components of energy at high frequencies. Consequently, here also cores with low eddy current losses are required for the transformers, not only to assure the faithful transmission of the pulse shape, but also to reduce heating to permissible values.

The use of magnetic powder might suggest itself for these high frequency purposes. However, this involves a three dimensional subdivision of the material. The effect of the particle separations in the direction of the flux is equivalent to a large series air gap in the core, and the net permeability, even with the best alloys, is much too low. With punched laminations, as they are made thinner to reduce eddy currents, the number required for a given stack-up increases. Then fabricating, handling, and insulating the thin laminations to form cores become a problem.

There is thus an area of high intrinsic permeability and low eddy current losses which is satisfied neither by powder cores nor, at the other extreme, by practical punched lamination structures. It is here that permalloy cores of tape 2 mils and less in thickness find their field of use. The tape may be insulated and formed into cores in a continuous operation as will be described. The magnetic circuit is essentially closed. For the wide-band application small toroidal cores of one mil tape accordingly were used. For the pulse transformer applications one and two mil permalloy tape in the form of larger rectangular cores found immediate successful use. The excellence of the results obtained in these designs is largely attributable to these materials.

Fabrication

The permalloys are well adapted to use in thin tape cores. They can be rolled to one mil and less with relative ease compared, for example, with silicon iron. Nor are their magnetic properties materially impaired in the process. Of the two permalloys that mainly have been used for such purposes molybdenum permalloy has the higher permeability. It consists of 4 per cent molybdenum, 79 per cent nickel, and the remainder iron. However, 45 permalloy has a higher saturation value. It consists of 45 per cent nickel and 55 per cent iron. Both these alloys are melted in an arc furnace, and, after hot rolling of the thicker sections, the strip is cold rolled to finished size. For the thinnest tapes the final reductions are carried on in a multibacked rolling mill with small work rolls. For some applications the tape is used at 1/4 mil and 1/8 mil thicknesses. The latter is obtained by plating an equal thickness of copper onto the tape and rolling the combination down to 1/4 mil. The copper then is removed by an acid bath, leaving the desired 1/8 mil tape. Cross sections of thin tape are illustrated in Figure 1.

The method of insulation that has been found best is by cataphoresis, that is, the electrodeposition of fine colloidal particles. In this process the tape is passed through a suspension of silicic acid in acetone. The tape is kept at a positive potential of from 5 to 45 volts with reference to the container. The charged particles of the acid powder are attracted to the tape and form a very uniform coating, the thickness of which is under the control of the operator. The tape is dried by means of hot air jets as it leaves the bath and is wound under tension on a mandrel to form the core. The coating so applied is quite adherent. The apparatus that has been developed for this process is illustrated in Figure 2. The insulated core is heat treated in an atmosphere of hydrogen, and when rectangular

Figure 1. Molybdenum permalloy tape of 1/8 mil, 1/4 mil, and one mil thickness

Thicknesses compared with that of human hair shown at right. Magnification 100×

Paper 46-27, recommended by the AIEE committee on communication and presented at the AIEE winter convention, New York, N. Y., January 21-25, 1946. Manuscript submitted November 23, 1945; made available for printing December 12, 1946.

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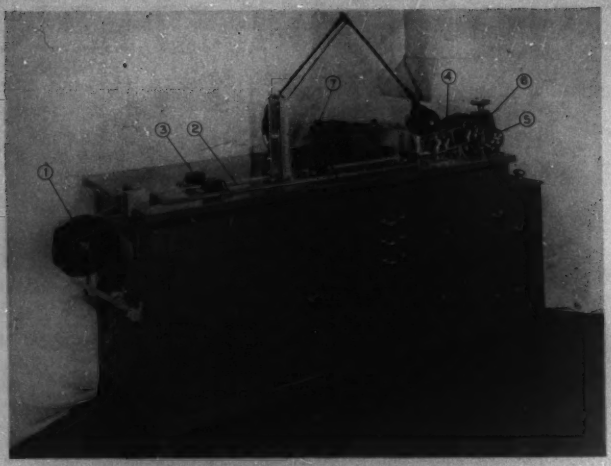


Figure 2. Cataphoresis insulating equipment

1—Tape supply spool and Prony brake
2—Cover for insulating bath
3—Motors for agitating suspension
4—Hot air jets
5—Mandrel on which core is wound
6—Take-up mechanism which winds tape under tension
7—Control panel

shaped it is held in clamps to maintain close dimensional tolerances. At the high temperatures the silicic acid dehydrates to silicon dioxide which provides the final interlaminar insulation. It also prevents welding of adjacent layers of tape during treatment. This process results in a fully adequate insulation and a typical packing factor of 80 per cent for one mil tape.

The cores so made are sufficiently rigid to require no strengthening by impregnation. Windings are applied to the closed cores by winding machines with circular shuttles. For some uses, a very small air gap is advantageous as will be described. The core is cut into halves using a wet rubber-bonded cutoff wheel. The windings are applied directly to the core halves. These are reassembled and the butting surfaces held together under pressure.

Application to Wide Band Transformers

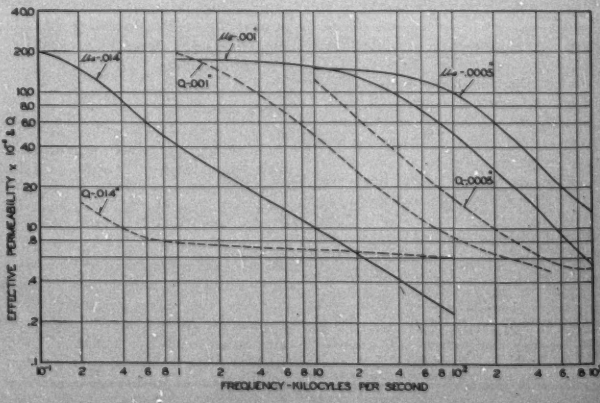
In the design of wide band transformers* for carrier telephone circuits, the problem is to obtain a sufficiently wide transmission band with low attenuation. Leakage inductance is a major factor in limiting this band. Reducing the leakage by closer coupling of the windings usually increases the winding capacitances which also restrict the range. Lower leakage therefore must come from the use of better cores which permit fewer turns without increasing the shunt attenuation. It is for such reasons that magnetic materials having higher permeabilities at frequencies above 50 kilocycles are needed.

Transformers in telephone circuits operate at low alternating voltages, and the flux densities in the cores are correspondingly low, less than 20 gausses. Molybdenum permalloy is characterized by very high permeability at low densities and also by very low hysteresis effects. This latter feature is valuable, since magnetic modulation might otherwise cause objectionable interchannel cross talk and noise. Figure 3 gives the effective permeability and Q of molybdenum permalloy tapes in the form of cores. A curve for 14 mil material also is given for purposes of comparison. As pointed out previously, the windings are applied to these cores with shuttle type winding machines. This permits a continuous magnetic circuit to be used and the high permeability of the tape to be fully retained in the core. The fact that the permeability of thin tape holds up at high frequencies is noteworthy and accounts for the low attenuation of the transformers. Figure 4 shows a typical core of one mil tape together with a transformer in which it is used.

Application in Low Voltage Pulse Transformers

Radar indicator circuits employ transformers passing low amplitude pulses of short duration. The high frequency components of the pulses correspond roughly to those of the wide band transformers and the design considerations requiring a high effective permeability core apply here also. However, the core material then is operated over a different portion of its magnetic characteristics from that for alternating current.

Figure 3. Effective permeability and Q of three thicknesses of 4-79 molybdenum permalloy as a function of frequency



* The design of the amplifiers in which these are used impose many other requirements, the discussion of which is beyond the scope of this paper.

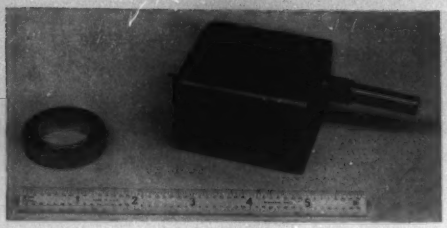


Figure 4. One mil 4-79 molybdenum permalloy core and transformer in which it is used

Operating range 64–3,200 kilocycles

Each unidirectional pulse conditions the material for the succeeding pulse. From the basic relation $e = -K_1NA \times (dB) \div (dt)$ each pulse demands a flux density change $\Delta B = (K_2Et) \div (NA)$, where E is constant during the pulse. For virgin material the initial flux density swing, $O-P_1-B_1$ leaves the material magnetized to the value B_1, as shown in Figure 5, the falling portions of the loop P_1-B_1 representing the decay occurring between pulses. The next cycle leaves the material magnetized to the value B_2, and so on. The steady state condition $B_n-P_n-B_n$ is reached when the falling portion of the loop is equal to the flux density change required by the pulse. The permeability that applies is then the ratio of the change in B to that in H for this cycle. For larger flux changes the loop becomes $B_r-P_r-B_r$ where B_r is near the retentivity of the material. This permeability value is always substantially less than the initial permeability and for molybdenum permalloy is in the order of 4,000 for a 1,000 gausses change. Reverse magnetization between pulses alters the phenomena, and this will be described under high power pulse transformers where it is more likely to occur.

The permeability values as described are of course reduced by eddy currents owing to the rapid change of flux during the pulse. For low density operation the characteristic of the material may be regarded as linear for analytical purposes. The equations for flux distribution, effective permeability, and losses for the linear case are given in the appendix. Ranges of values are given in the graphs of Figures 6 and 7.

These graphs illustrate the extreme variation of flux density which may be caused by eddy currents and the corresponding low permeability which may obtain with pulses of short duration, that is, small values of t. They also illustrate that this loss of permeability may be recovered to any desired extent by using thinner magnetic material, that is, smaller values of α. These considerations have led to the use of thin tape in low voltage as well as in high voltage pulse transformers. In a typical case one mil molybdenum permalloy was required. The core was toroidal and very similar to that illustrated in Figure 4. By this means it was possible in the transformer to transmit one microsecond square pulses with 0.05 microsecond sides without appreciable distortion.

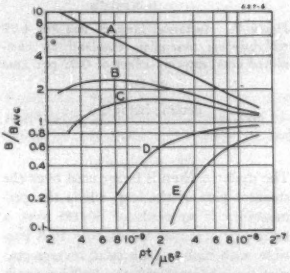


Figure 6. Relative flux density distribution in tape with square pulse voltage excitation

The average flux density B_{AV} increases linearly with time

A—$y = \frac{\delta}{2}$ (surface)

B—$y = \frac{5}{12}\delta$

C—$y = \frac{3}{8}\delta$

D—$y = \frac{\delta}{4}$

E—$y = 0$

ρ = resistivity of tape in ohm-centimeters
δ = thickness of tape in inches
t = time in seconds
μ = d-c permeability
y = distance from mid-plane of tape in inches

Application in High Power Pulse Transformers

These transformers are used in the modulator circuits of radar transmitters to impress pulses on magnetrons. Power ranging from 100 to 1,000 kw is carried by these transformers for the duration of each square pulse. The high winding voltages range from 10 to 30 kv. Most uses demand small size and weight in apparatus, especially air-borne equipment. It is thus necessary that transformers for these powers insulated for the high voltages be designed on small core structures; for example, 2 pounds for 300-kw pulses. Further, the magnetrons to which the transformers are connected are voltage

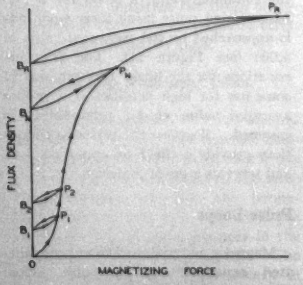


Figure 5. Sequence of flux-density changes with repeated unidirectional pulses, namely, $O-P_1-B_1$, $B_1-P_2-B_2, \cdots B_n-P_n-B_n$; larger changes result in $B_r-P_r-B_r$

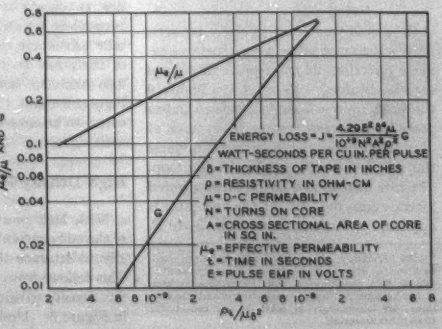

μ_e/μ
μ_e/μ AND G
G
ENERGY LOSS = $J = \frac{4.29E^2\delta^4\mu}{10^{18}N^2A^2\rho^2}G$
WATT-SECONDS PER CU IN. PER PULSE
δ = THICKNESS OF TAPE IN INCHES
ρ = RESISTIVITY IN OHM-CM
μ = D-C PERMEABILITY
N = TURNS ON CORE
A = CROSS SECTIONAL AREA OF CORE IN SQ. IN.
μ_e = EFFECTIVE PERMEABILITY
t = TIME IN SECONDS
E = PULSE EMF IN VOLTS
$\rho t/\mu\delta^2$

Figure 7. Curves for computing the effective permeability and the eddy current loss in tape with square pulse voltage excitation

When t is taken as the pulse length, J is the total loss during and after the pulse, assuming that the voltage is zero after the end of the pulse

sensitive in their operation. Appreciable magnetizing current being drawn through the source impedance is objectionable as it tends to reduce the voltage applied. All these factors impose severe demands on the core material requiring thin tape of the high quality obtainable in the permalloys.*

Range of Flux Density

The power capability of the transformers obviously is governed by the flux density range in the core material. Where there is simply decay of the flux between pulses, the minor $B-H$ loops traversed are like those shown in Figure 5. The useful flux density range is limited by the difference between saturation and retentivity. Generally speaking, as the magnetic quality of materials is improved and the permeabilities increase, the loops become more nearly square. This is illustrated for the two permalloys in Figures 8 and 9. Consequently, the difference between saturation and retentivity becomes less.

The available flux range can be increased substantially by the addition of an appropriate air gap. This is illustrated by the dotted hysteresis loop of Figure 8 for molybdenum permalloy with a 0.02 per cent air gap. The loop is sheared compared with the normal loop, and the apparent retentivity has been reduced to about 400. The flux density range now is increased to B_s-B_r', approximately 8,100 for the proportions shown in the figure. The maximum permeability, however, has been reduced, which represents some sacrifice in efficiency to obtain the flux range. The principle of adding an air gap for this purpose has found general use where reversal between pulses, as will be described, was not effective.

Reverse Magnetization

If, during the long interval between pulses, the material is magnetized in a reverse direction, an even wider flux range can be obtained. Referring to Figure 9 the peak reverse current between pulses provides a reverse magnetizing force of H_r. This causes the material to traverse the $P-B_r-A-B_s$ section of the loop. The rate is slow enough not to be affected by eddy currents. When the next pulse is applied, the flux can swing from B_s to P.

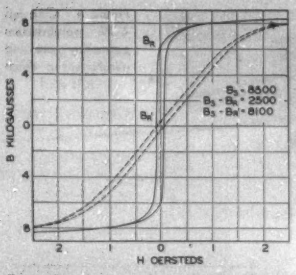


Figure 8. Hysteresis loop of one mil 4-79 molybdenum permalloy obtained on completed core, showing effect of 0.02 per cent air gap

Packing factor 0.8

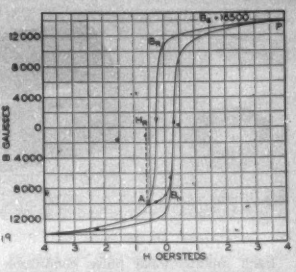


Figure 9. Hysteresis loop of 2 mil 45 permalloy obtained on completed core, showing flux density cycle with reverse magnetizing force

Packing factor 0.9

The material then is being used over the steepest part of the loop where the permeability is upwards of 50,000 over a large part of it (see Figure 9). It is possible with high enough peak reverse current to make available the limiting range from the retentivity below the axis to saturation above, that is, 10,000 + 16,500, or a total swing of 26,500 gausses for 45 permalloy. It is clear from the illustration that the reverse magnetizing force to be very effective must be at least greater than the coercive force of the material. It is also clear from comparing the solid with the dotted loops of Figure 8 that much better results can be obtained with a closed magnetic circuit than with an air gap. A reverse direct current fed to the winding has been used experimentally, raising the limiting flux swing to twice saturation. This has not been found of sufficient advantage in the pulse transformer cases considered to warrant the attendant circuit complications.

Reverse magnetization between pulses has been used very successfully in practice to obtain wide flux swings. The permalloys are especially well adapted to take advantage of this feature by virtue of their low coercive forces, which are 0.05 and 0.3 oersted as illustrated in Figures 8 and 9. These values permit reversal to be effected with minimum magnetizing forces.

High Density Pulse Magnetization

With high power operation the effect of the eddy currents on short pulses is usually to saturate the surface of the tape. This follows from the large differences in flux density within the tape as illustrated in Figure 6. Under these conditions the characteristics of the material are not at all linear, and the equations previously referred to do not directly apply. Unfortunately, the rigorous analysis of the nonlinear case is, at the least, laborious.

The high density behavior may be analyzed readily by making simplifying assumptions appropriate to the high permeability alloys. It will be observed from Figures 8 and 9 that the d-c permeability over most of the range is exceedingly high with a rapid transition to saturation. Accordingly, let infinite d-c permeability but finite saturation be assumed. At the start of the pulse the flux is confined to the surfaces of the tape which saturate. The saturated regions propagate toward the center of the tape until the pulse ends or until the entire lamination is saturated. Equations for permeability and loss for this case are derived in the appendix.

The behavior of actual tape of the best magnetic materials approximates that described. For example, for 1.1-mil tape the computed value of 5,050 for a 2.1-microsecond pulse using these equations is approached by the measured value of 4,000 (see Figure 11). The previous equations for the linear case are also of some use for high densities if a proper averaged value of d-c permeability is assumed. Together the two sets of equations provide a check on empirical data and serve as a guide in design.

Pulse Loops

Magnetic materials and cores are evaluated experimentally by pulse loops. The measuring circuit operates on the same principle as the familiar hysteresograph often used for obtaining 60-cycle loops. A schematic of the pulse circuit

* 4-43 Permalloy, a new alloy, also has been used, to a limited extent. It consists of 4 per cent molybdenum, 43 per cent nickel, and the remainder iron. It is characterized by high resistivity and the core losses are accordingly at least 30 per cent lower than other materials.

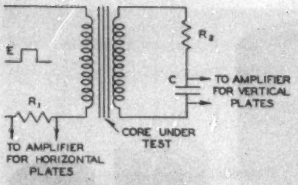


Figure 10. Simplified circuit schematic for presentation of pulse loop on oscilloscope screen

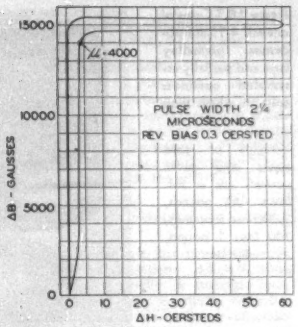


Figure 11. Pulse loop of 1 mil 4-79 molybdenum permalloy with reverse bias obtained on completed core without air gap

Packing factor 0.8

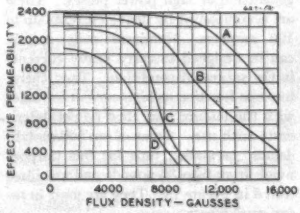


Figure 12. Effective permeability with 5 microsecond pulses obtained in completed core of 2 mil 45 permalloy without air gap

Packing factor 0.9

A—Reverse d-c bias, 0.52 oersted
B—0.28 oersted
C—0.078 oersted
D—No bias

for oscilloscope presentation is shown in Figure 10. The lower portion of the loops obtained defines the material, the return trace varying with circuit conditions. Calorimetric methods are relied upon for accurate loss determinations. Figure 11 shows the pulse loop of one-mil molybdenum permalloy tape in a core with 0.3 oersted reverse bias. The effective permeability is seen to be 4,000 with a flux swing of 14,000 gausses. The loop was taken with a reverse d-c bias instead of peak reversal between pulses, since the measuring circuit is better adapted to the former procedure. Peak reversal yields somewhat less flux swing, in this instance about 12,500 gausses. Figure 12 shows how different reversals affect the pulse permeability of a 45 permalloy core. The data were obtained from pulse loops with varying average flux densities. Figure 13 gives data on the pulse permeability of two thicknesses of molybdenum permalloy with small air gaps.

Figure 14 shows a pulse transformer which has found wide use in air-borne radar equipments. The core shown with it is the one on which the pulse loop of Figure 11 was taken. Figure 15 shows a large pulse transformer with a 45 permalloy core. In contrast there is shown one of the smallest transformers of this type. These illustrate the range of application of the superior magnetic properties of thin permalloy tape.

Application to Nonlinear Coils

It is characteristic of molybdenum permalloy mentioned here that the magnetization curve is very steep, that it has a relatively sharp transition to the saturated condition, and that the permeability there is very low. Valuable use has been made of these features in the generation of groups of harmonics. The basic circuit is shown schematically in Figure 16. The generator provides current of the fundamental frequency to which the series coil and capacitor are resonant. During that part of the cycle where the nonlinear coil has a high inductance, the capacitor C_1 is charged. As the coil begins to saturate its inductance falls and the capacitor discharges through it. This carries the material farther into the saturated region where the permeability is very low. The coil thus acts as a magnetic switch by which a sharply peaked current pulse rich in harmonics is generated. These harmonics pass through appropriate equalizers and filters to supply the carrier currents to multichannel coaxial and other carrier systems. Coils of this type are attractive as modulating devices, as they are stable and have an indefinitely long life compared to vacuum tubes.

The efficiency of the device requires that the inductance during the nonsatu-

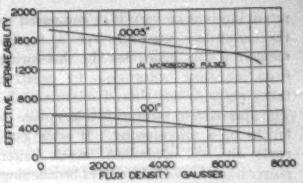


Figure 13. Effective permeability characteristics of 4-79 molybdenum permalloy obtained in completed cores with small air gaps

Packing factor 0.7 for 1/2 mil tape and 0.8 for 1 mil tape

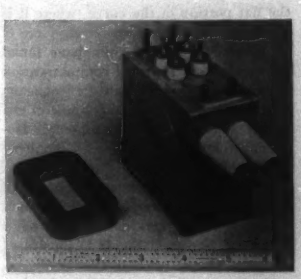


Figure 14. Rectangular core of 1 mil 4-79 molybdenum permalloy and pulse transformer in which it is used

Pulse power 100 kw

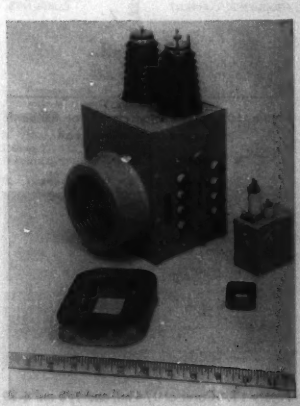


Figure 15. Rectangular core of 2 mil 45 permalloy weighing 3 pounds and 1/4 pound core of one mil 4-79 molybdenum permalloy with the pulse transformers in which they are used

rated interval be very high compared to the saturated interval. For a fundamental of 120 kilocycles the flux swing from negative saturation to positive takes place in less than 4 microseconds. The approach to saturation takes place in tenths of a microsecond. If eddy currents are not minimized, much larger power input is needed to avoid broadening the peaked pulse and so reducing the output of high frequency harmonics. These considerations again dictate a core of very thin molybdenum permalloy tape, in this instance 1/4 mil. This core in a specific case has differential permeability, with eddy currents, over the steep part of the curve of more than 10,000. This is in striking contrast to the value of 3 at the flat portion of the curve, where it is driven by the peak magnetizing force of 20 oersteds. Similar coils have found military uses. In tank communication circuits they provide means for frequency modulation of a desired harmonic of the carrier input. The fundamental frequency there is 400 kilocycles requiring 1/8 mil tape. In order to operate effectively at this frequency and with small power, the cores were designed with a diameter of 0.3 centimeter and weigh only 20 milligrams. Figure 17 illustrates coils of this type.

Nonlinear coils have found further important use as magnetic switches in the generation of high power pulses. These are accompanied by heavy currents up to 100 amperes. Nonlinear coils readily can be designed to carry heavy currents in the saturated condition. They therefore can function as high current switches with the feature that they do not deteriorate with use. Cores of one mil molybdenum permalloy tape for this purpose weigh from 2 to 30 pounds and are illustrated in Figure 18. They are used in radar equipments.

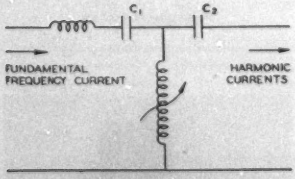


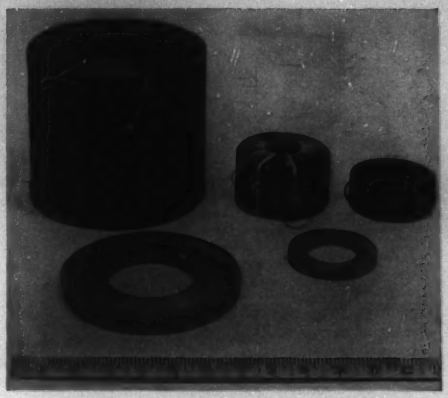
Figure 16. Elementary circuit for harmonic generation by nonlinear coil

Figure 17. Cores of 1/4 mil and 1/8 mil 4-79 molybdenum permalloy used in harmonic generator coils

Tape is wound on ceramic forms for mechanical support. Weights of metal 60 and 20 milligrams, respectively

Figure 18. Cores of one mil 4-79 molybdenum permalloy tape and partially assembled nonlinear coils in which they are used

Weights of core stacks and pulse powers are as follows: 30 pounds, 1,000 kw; 2 pounds, 100 kw; 1 pound, 50 kw



Appendix

Voltage Pulse Magnetization—Linear Case

The applied voltage is taken as constant for the duration of the pulse which is the usual condition for pulse transformer operation. If a homogeneous material with constant permeability and not saturable is assumed, the following expressions are derived* from Maxwell's equations by straightforward methods. The flux distribution during the pulse after an interval of time t is given by

$$\frac{B}{B_{avg}}=\frac{2.025\mu\delta^2\times10^{-8}}{\rho t}\left[\frac{2y^2}{\delta^2}-\frac{1}{6}+\frac{49.3\rho t}{\mu\delta^2 10^{-8}}-\frac{2}{\pi^2}\sum_{n=1}^{\infty}\frac{(-1)^n}{n^2}\cos\frac{2n\pi y}{\delta}\exp\frac{-487n^2\rho t}{\mu\delta^2 10^{-8}}\right] \quad (1)$$

where the average flux density in the tape is

$$B_{avg}=\frac{15.5Et}{NA}10^{+8}$$

gauss.

The effective permeability, defined for pulses as the ratio of the average flux density in the tape to the magnetomotive force at the surface, at time t during pulse is given by

$$\mu_e=\frac{49.3\rho t}{\delta^2}\times10^{+8}\left[\frac{1}{3}+\frac{49.3\rho t}{\mu\delta^2 10^{-8}}-\frac{2}{\pi^2}\sum_{n=1}^{\infty}n^{-2}\exp\frac{-487n^2\rho t}{\mu\delta^2 10^{-8}}\right]^{-1} \quad (2)$$

The total energy loss due to eddy currents during and after the pulse, assuming that the voltage after the pulse is zero for infinite time, is given by

$$J=\frac{4.29E^2\mu\delta^4}{10^8N^2A^2\rho^2}\left[\frac{49.3\rho T}{\mu\delta^2 10^{-8}}-\frac{1}{15}+\frac{6}{\pi^4}\sum_{n=1}^{\infty}n^{-4}\exp\frac{-487n^2\rho T}{\mu\delta^2 10^{-8}}\right]$$

watt-seconds per cubic inch per pulse (3)

This equation is plotted in Figure 7. The conditions assumed apply to a well-designed pulse transformer in the usual circuit. There the voltage in the relatively long interval between pulses is small, and the total flux decays so slowly that the eddy current losses from this source can be neglected. On the other hand, eddy current losses accompany the rapid transition from a nonuniform to a uniform distribution of the flux within the tape after the pulse, and these losses are included in the foregoing expression.

If the voltage after the pulse is not small, no general expression can be given as the loss then depends on the particular conditions. However, the loss during the pulse itself, which is the major part, is determined and is given by

$$J_T=\frac{2.54E^2\delta^2}{N^2A^2\rho}\left[\frac{T}{12}-\frac{20.8\mu\delta^2}{10^{11}\rho}\sum_{n=1}^{\infty}\times\frac{1-\epsilon^{-\frac{487n^2T\rho}{10^{-8}\mu\delta^2}}}{n^4}+\frac{5.20\mu\delta^2}{10^{11}\rho}\sum_{n=1}^{\infty}\frac{1-\epsilon^{-\frac{97.6n^2T\rho}{10^{-8}\mu\delta^2}}}{n^4}\right]$$

watt-seconds per cubic inch per pulse (4)

where

* By Doctor L. A. MacColl, Bell Telephone Laboratories, Inc.

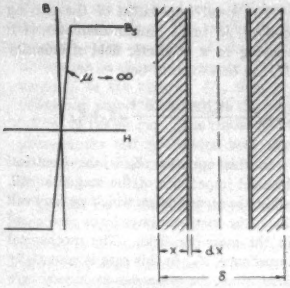


Figure 19

μ = the permeability relative to free space without eddy currents
δ = the thickness of the tape in inches
y = the distance from the mid-section of the tape in inches
ρ = the resistivity in ohm-centimeters
t = the time in seconds
T = pulse length in seconds
A = the cross section of the core in square inches
N = the number of turns in the winding
E = the electromotive force applied to the winding, in volts

Current Pulse Magnetization—Linear Case

The corresponding equations for the current pulse are given for completeness:

$$B = \frac{\mu NI}{2.02l}\left[1 - \frac{4}{\pi}\sum_{n=1}^{\infty} n^{-1} \times \left(\sin\frac{n\pi}{2}\right)^2 \sin\frac{n\pi y}{\delta} \exp\frac{-122n^2\rho t}{\mu\delta^2 10^{-6}}\right] \text{ gausses} \quad (5)$$

$$\mu_e = \mu\left[1 - \frac{8}{\pi^2}\sum_{n=1}^{\infty} n^{-2} \times \left(\sin\frac{n\pi}{2}\right)^4 \exp\frac{-122n^2\rho t}{\mu\delta^2 10^{-6}}\right] \quad (6)$$

$$J = \frac{2.58N^2I^2\mu}{10^8 l^2}\sum_{n=1}^{\infty} n^{-2}\left(\sin\frac{n\pi}{2}\right)^4 \times \left(1 - \exp\frac{-122n^2\rho T}{\mu\delta^2 10^{-6}}\right)$$

watt-seconds per cubic inch per pulse (7)

where l is the length of magnetic circuit in inches, and I is the current in amperes, constant during pulse and zero thereafter. J includes the losses during and after the pulse.

Voltage Pulse Magnetization—Nonlinear Case With Saturation

For this case an idealized magnetization curve as shown in Figure 19 is assumed. With infinite permeability the tape is divided at any instant into surface sections which are saturated and a central section devoid of flux as shown in the figure.

For a section of tape of thickness δ and unit length and width, the eddy current

$$i_e = 2\Delta B_s K_1 \frac{dx}{dt} \cdot \frac{2.54x}{2\rho} \text{ amperes}$$

where ΔB_s is change in flux density from the initial value to saturation. $\Delta B_s = B_s$ when the material originally is unmagnetized. Since the permeability is infinite, the magnetomotive force at the surface is only that required to maintain the eddy current. Whence, $H = 0.495i_e$ oersted. The change in average flux density, $\Delta B_{avg} = (2x\,\Delta B_s) \div \delta$. Whence the effective permeability

$$\mu_e = \frac{\Delta B_{avg}}{H} = \frac{1.59\rho}{K_1\delta\dfrac{dx}{dt}}$$

For the winding

$$E = 2\Delta B_s K_1 \frac{dx}{dt}\frac{NA}{\delta}$$

By substitution

$$\mu_e = \frac{3.18\rho NA\,\Delta B_s}{\delta^2 E} \quad (8)$$

Since the change in average flux density is linear with time, this also may be written

$$\mu_e = \frac{0.493\rho T_0 10^{+8}}{\delta^2}, \text{ where } T_0 = \frac{\Delta B_s}{\Delta B_{avg}} T \quad (9)$$

where T_0 is time in seconds to saturate tape without eddy currents. It is also the time required to saturate the entire cross-section of the tape under the assumed conditions. As before, μ_e is relative to free space, ρ is the resistivity in ohm-centimeters, A is the core area in square inches, δ is the tape thickness in inches, B_s is in gauss, E is in volts, N turns, and T is pulse length in seconds.

Since the effective permeability is constant during the pulse, the loss is proportional to the square of the flux density and may be written

$$\text{loss} = \frac{6.52VF\Delta B_{avg}{}^2 10^{-8}}{\mu_e} \text{ watts} \quad (10)$$

where V is net core volume in inches cubed, F is in pulses per second, ΔB_{avg} is the change in average flux density to end of pulse. Since magnetic energy is proportional to $\int HdB$, there is no storage of energy at any time under the assumed condition of infinite permeability.

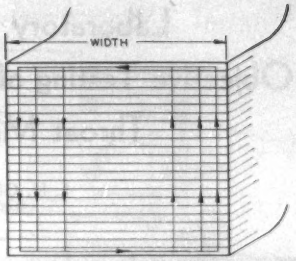


Figure 20. Distribution of intersheet eddy currents in cross section of core

Resistivity across stack $\gg$ than resistivity of tape. The dimension for the width shown is to be used for the thickness, δ, in the equations when these are applied to the core

Intersheet Eddy Currents

It is worth noting that all the foregoing equations for tape may be employed in dealing with intersheet effects in a core. The resistivity across the stack is ordinarily very high compared to that of the tape The eddy currents then run essentially perpendicular to the tape, and the current loops are completed in the end tapes as illustrated in Figure 20. The distribution of flux and currents in the cross section is then the same as that in a strip having resistivity equal to that across the stack, thickness equal to the stack width, and of indefinite extent in the remaining directions. It is only necessary to substitute the width w for δ in the expressions and graphs. Evidently, when the stack resistivity equals $(\rho w^2) \div \delta^2$, the stack losses are equal to those contributed by the tape.

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Laboratory Method for Objective Testing of Bone Receivers and Throat Microphones

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MEMBER AIEE

THE development and testing of inertia-type transducers require equipment similar to the artificial ear used in the testing of air conduction receivers.

The problem of building a reliable artificial ear is relatively simple compared to that of constructing an artificial mastoid for testing bone conduction receivers, or an artificial throat for testing throat microphones. The artificial ear employs an air cavity, which simulates the cavity of the ear and couples the receiver under test to a condenser microphone, in order to measure the pressure produced in the cavity by the receiver. In the case of the bone conduction receiver, the role of the air cavity is played by a layer of skin, coupling the bone conduction receiver to the mastoid bone. A similar situation is encountered in the case of throat microphones, where the larynx is coupled to the throat microphone through an interposed layer of skin. The properties of the layer of skin vary over a very wide range, making it difficult to determine what is the average impedance looking into the human head or throat. There is also a controversy as to whether one should measure the pressure or the velocity transmitted through the layer of skin.

An artificial throat suitable for testing throat microphones must have a vibrating platform capable of imparting a velocity to a throat microphone through a filter simulating the layer of skin. The platform must be large enough to make the microphone response independent of small changes in orientation or locating of the microphone on its surface. The velocity of this platform should have some simple law of distribution over the desired frequency spectrum (preferably a uniform distribution) of approximately 50 to 10,000 cycles. At the same time, the platform must have a sufficiently high mechanical impedance in order for its motion not to be affected by the high impedance of the tested throat microphone at its points of resonance. In the selection of a proper system, consideration was given to a design of platform which would be controlled by one of the three possible parameters, namely: resistance, stiffness, or mass. Resistance control has the advantage of uniform velocity distribution over the frequency range, but it was very difficult to find a physical embodiment of a stable mechanical resistance. Stiffness control is difficult to realize, since in a physical stiffness element there must be some mass present.

A mass controlled platform on the other hand is relatively easy to construct. A platform having a mass of approximately 4,000 grams can be driven with a relatively small expenditure of wattless power. For example, in order to impart an amplitude A of 10^{-7} centimeters at 10,000 cycles (which amplitude is far in excess of the amplitude of vibration actually encountered) to a mass M of 4,000 grams, a wattless power of $\omega^2 MA^2 \times 10^{-7}$ or 0.001 watt, is required.

In an early model of the artificial throat, one end surface of a brass cylinder, approximately $3^1/_4$ inches in diameter and $3^1/_2$ inches in length, was used as the driving platform. The opposite end of the cylinder was designed to support a driving "voice" coil. This voice coil moves in the field provided by the cylindrical air gap of a 50 watt loud-speaker structure (Jensen, PM type) (5 in Figure 1).

In order to insure mass-controlled operation, the cylinder is supported and guided by a system of extremely flexible springs, resulting in a natural resonant frequency for the mass and stiffness combination of approximately 1 cycle per second. The power which has to be supplied to the driving coil can be estimated approximately as follows.

The total impedance of the driving coil of N turns and a diameter (D), moving in a magnetic field of intensity H, can be shown to be:

$$Z_t = Z_e + \frac{\pi^2 (NHD)^2 \, 10^{-9}}{Z_m} = Z_e + Z_d$$

In this equation Z_e is the electrical blocked impedance of the magnetic coil, while the second term, which we may call Z_d, is the motional impedance of the coil in the magnetic field. The mechanical impedance, Z_m, in this case is essentially $j\omega M$, since the resonance frequency here is far below the frequency of forced vibrations at which the mass is driven. The motional impedance Z_d is the part of the total impedance which is responsible for the energy transfer from the coil into the mass of the cylinder. We can, therefore, state that the efficiency of the driving system is approximately proportional to $\left| \frac{Z_d}{(Z_e + Z_d)} \right|$, or, since Z_d is in this case negligible in comparison with Z_e, the efficiency is equal to $\left| \frac{Z_d}{Z_e} \right|$. Z_d is approximately equal to 0.025 ohm for actual values of $N = 250$, $D = 2^1/_2$ inches, and $H = 15{,}000$. Thus, with Z_e equal to approximately 250 ohms at 10,000 cycles, we have an energy transfer efficiency at 10,000 cycles equal to 10^{-4}. Therefore in order to impart to this mass an amplitude of 10^{-7} centimeters at 10,000 cycles, the necessary power input to the coil is 10 watts. The actual amplifier used to drive the artificial throat with a power output capacity of 50 watts was found sufficient to satisfy all requirements encountered in development work and testing.

Figure 1 shows the cross section of the artificial throat described above. The cylinder (1) is supported by four springs (2 and 3), illustrated in Figure 2. These springs serve to guide the cylinder in the axial direction. They are extremely flexible in a direction perpendicular to their plane, while they are very rigid in a radial direction. Two such springs, displaced angularly by 90 degrees to each other, are used near each end of the cylinder. These springs were punched out of thin phosphor bronze sheet, in order to keep the resonant frequencies of their free spring portion S, connecting the inner and outer rings of the springs, considerably below 50 cycles. This is important in order to prevent these springs from reacting upon the motion of the cylinder in the useful frequency range. The weight of the cylinder is supported by four very compliant helical springs

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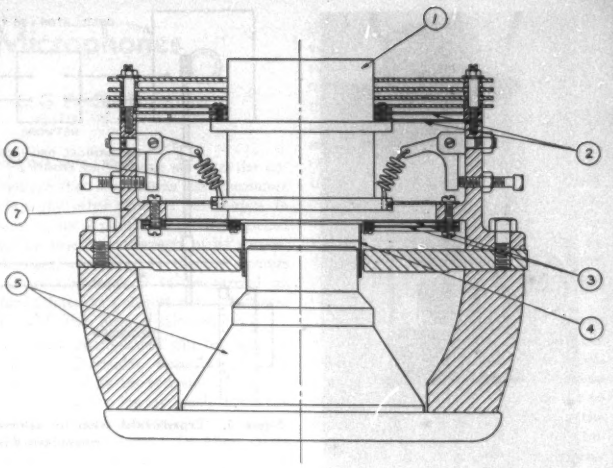
The author acknowledges the co-operation of the Sonotone Corporation in sponsoring the development work on the apparatus described. He desires also to express his appreciation to F. P. Greenwood, M. E. Zaret, and Jack Sobol for their co-operation in the development of the testing equipment and to E. A. Pearson for many valuable discussions during the progress of the work.

(6), which are permitted to be sufficiently extended to support the weight of the cylinder. The position of the helical springs can be adjusted by means of levers mounted in the cylinder (7), thus providing for proper centering of the voice coil (4) in the air gap. The throat microphone under test is shielded both magnetically and electrically by the series of disks shown in Figure 1.

The system of compliant springs maintains the mass of the cylinder effectively floating in air and does not affect its pure mass impedance character. This behavior of the cylinder is, however, disturbed at the frequency at which the cylinder ceases to be a rigid mass and becomes a half wave length transmission line with distributed parameters. This change occurs for a brass cylinder of the dimensions used at a frequency of approximately 17,500 cycles. Therefore, at frequencies whose second and third harmonics are equal to 17,500 cycles, marked resonance effects were observed. This resonance was shifted to a higher frequency by substituting stainless steel for brass, since the velocity of sound in stainless steel is considerably higher than in brass. By using stainless steel cylinders of a shape slightly different from the one shown in Figure 1, it was possible to move this half wave resonant frequency up to 27,000 cycles. In this way, the first resonant effect obtained was in the neighborhood of 9,000 cycles.

In order to obtain a uniform velocity of the platform in the frequency range required, it is necessary to energize the driving coil with a current increasing linearly with frequency. This was accomplished by providing the input of the linear 50-watt amplifier with a simple dividing network, consisting of condensers and resistors. Figure 3 shows the velocity distribution of an artificial throat containing the brass cylinder. Two peaks, one at 5,800 and one at 8,700 cycles are seen in this figure. They are due to a very small amount of second and third harmonics present in the output of the driving amplifier. The peaks are sharp on account of the very high Q of the brass cylinder. In the final design, using a stainless steel cylinder, the velocity distribution turned out to be uniform within ± 2 decibels in the range from 50 to 10,000 cycles.

The velocity calibration was obtained by means of the experimental setup shown in Figure 4. It consists of a second voice coil attached to the moving platform of the artificial throat under test. This coil moves inside a stationary magnetic field provided by a permanent magnet loud speaker field structure m. The magnet is



suspended from a substantially vibration-proof mounting shown in the figure. This mounting consists of two heavy cylinders connected to each other by means of three very flexible springs and a large oil dash pot to provide damping. The upper of the two cylinders is suspended from the ceiling by means of a set of three chains

Figure 1. Cross-sectional view of artificial throat

1—Driving mass
2 and 3—Guide springs
4—Driving coil (voice coil)
5—Permanent magnet loudspeaker structure
6—Supporting springs
7—Supporting structure for driving mass

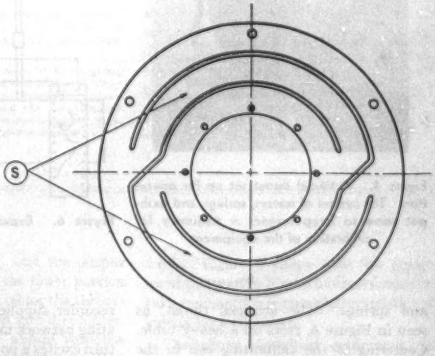


Figure 2. Support springs of artificial throat (2 and 3 in Figure 1)

S—Free spring portion

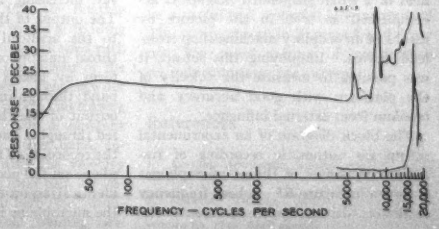


Figure 3. Frequency response curves for 50-watt artificial throat with solid brass driving mass

Upper curve is typical frequency response of artificial throat. Lower curve is 15 decibels lower than upper for location of frequency of upper peak

Figure 4. Artificial throat set up for operation. The system of masses, springs, and dashpot serve to keep magnet *m* stationary for calibration of the equipment

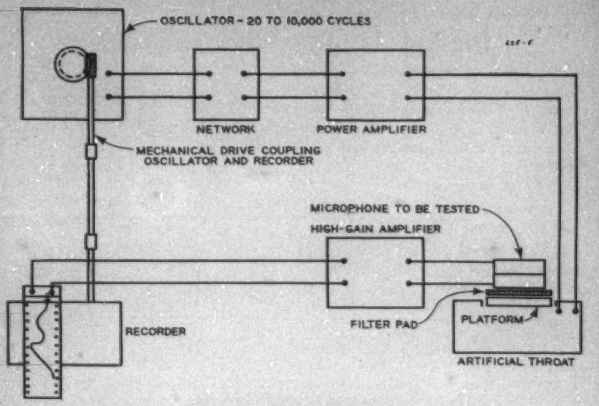


Figure 5. Experimental setup for automatically recording frequency response of throat microphone driven by artificial throat

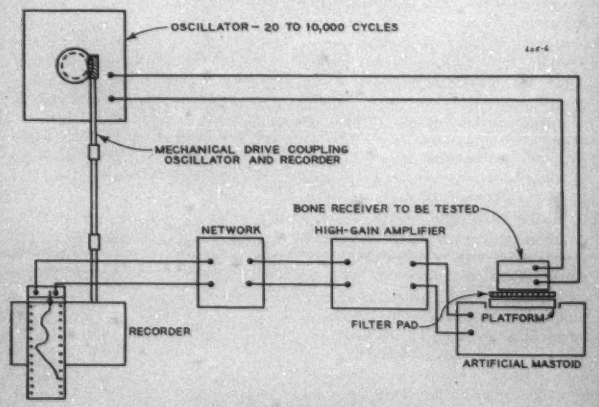


Figure 6. Experimental setup for automatically recording frequency response of bone receiver driving an artificial mastoid

and springs. The artificial throat, as seen in Figure 4, rests on a heavy table. Centering of the calibrating coil in the field of a small suspended magnet is accomplished as seen in the picture by means of an ordinary machine shop cross-feed device. Employing this set-up, it was possible to measure the velocity of the platform with good accuracy and freedom from external influence.

The block diagram of an experimental set-up for automatic recording of frequency responses of throat microphones is shown in Figure 5.[2] A beat frequency oscillator, driven by the motor of the recorder, supplies a voltage to the attenuating network mentioned above, which in turn excites a power amplifier with a voltage increasing linearly with frequency. The output of the power amplifier is fed to the artificial throat which drives a throat microphone (fastened to its platform by means of a compliant elastic band) through an interposed filter pad. The output of the throat microphone is then fed through a linear high gain amplifier to the recorder. The position of the microphone on the platform is not critical and identical response curves are obtained when the microphone is shifted on the platform.

The choice of a proper filter pad is the most difficult part of the problem. A filter pad should simulate the impedance looking into the human throat through the skin (or, in case of bone receivers, into the human head). This impedance has mainly stiffness and loss components. It was found possible to simulate either of the components by means of properly chosen pads. However, to date, serious difficulties have been encountered in constructing a pad that would give faithful reproduction of both parameters and thereby obtaining curves which are a true picture of the sensations received by the

Inertia Throat Microphones

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Synopsis: This paper deals with the theory and design of magnetic inertia throat microphones. Especial attention is given to the treatment of sound power and high articulation throat microphones. The sound power microphones described contain a double frequency, undamped vibrating system, while the high articulation microphones have damping introduced, which reduces the low frequency peak with resultant increase in articulation. Wide range frequency response is obtained from the neighborhood of 100 cycles, extending up to 3,000, 4,000, or 5,000 cycles, as may be desired. These microphones have a band pass filter character with a sharp high frequency cutoff. This cutoff is desirable in order to cut out high frequency noises.

IT IS frequently necessary to send messages from noisy surroundings, such as machine shops, airplanes, and battlefields. For example, although the noise levels found in industrial plants or aircraft are often of the order of 100 or more decibels, communication must be maintained at all times. This creates the need for a discriminating microphone, that is, a microphone which will attenuate substantially the undesired sounds to favor the particular desired message. The throat microphone is such a discriminating microphone, as it is highly sensitive to vibrations transmitted to it by bodily contact with the sound-producing throat while it is quite insensitive to sound waves transmitted by air.

A throat microphone also has the advantage that it produces less discomfort than any other style, is less subject to shifting out of position or getting knocked off because of movements of its wearer. Another advantage is that it permits normal conversation to be carried on unrestricted to a degree not approached by any other form of microphone.

Throat microphones can be built on different principles, according to the method used for the conversion of acoustic into electric energy, such as carbon chambers, crystal microphones, and electromagnetic systems. Of these three kinds of elements, as will be shown, the electromagnetic system is especially well suited to provide a high articulation throat microphone.

Throat microphones reproduce speech by picking up the vibrations of the larynx rather than the sound waves generated in the air by the speaker. High frequency vibrations picked up from the larynx are subject to considerably greater attenuation than low frequency vibrations, since these high speech frequencies generally are produced in the forward portion of the mouth and have to pass over a long path of soft flesh to reach the larynx. In addition, the larynx is covered with a sheath of compliant skin, which attenuates the higher frequencies still further. The throat microphone therefore should be designed to differentiate strongly in favor of the higher frequencies of the vibrations of the larynx.

Because throat microphones operate while pressed against the throat or other portion of the human body, it is necessary to enclose the working mechanism entirely within a rigid housing in order to prevent external forces from affecting the air gap. For the same reason, it also becomes desirable to use the inertia principle in the design of such microphones.*

In short, an electromagnetic throat microphone should favor the higher speech frequencies and be enclosed in a rigid housing, which latter calls for the use of the inertia principle.

The inertia unit consists of an electromagnet L_1 supported by a spring C_1, as represented in Figure 1. The electromagnet L_1 consists of two small Alnico magnets, a central core with a coil wound around it, and a yoke and pole plate. C_1 is an S-shaped spring, supporting the electromagnet and forming the working air gap between its central portion and pole surfaces. This electromagnet struc-

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The authors thank the management of the Sonotone Corporation for its approval of this project. They also are indebted to Mr. H. A. Pearson for many constructive discussions during the development program and to Mr. F. P. Greenwood and Mr. J. A. Kucher for carrying out the experimental work.

* E. H. Greibach, United States patents 2,255,249 and 2,255,250.

head in the case of bone conduction, or a true output of the human throat as it affects a throat microphone. While perforated rubber pads were found suitable to simulate the stiffness component of the skin and while pads of damping material, like "Viscoloid," have given a fair approach to the loss component of the skin, it was difficult to find a pad or combination of pads to simulate both stiffness and resistance together and in proper proportion.

It is readily seen that the artificial throat described above can also be used as an artificial mastoid. In the case of the artificial mastoid, the floating cylinder is driven by a bone conduction receiver through a filter pad simulating the skin over the mastoid bone, and the output of the coil mounted on the lower portion of the cylinder (driving coil for the throat) is then amplified and fed into a recorder. When it is desired to obtain response curves representing the force transmitted through the filter pad into the floating cylinder, it is necessary to use a dividing network (similar to the network used with the artificial throat) in the output of the linear high gain amplifier. This network will then deliver a voltage increasing linearly with frequency for a constant input voltage. On the other hand, response curves, representing the velocity transmitted through the filter pad, are obtained by using the linear high gain amplifier without an additional dividing network. Figure 6 shows how the equipment pictured in Figure 5 is rearranged to take frequency response characteristics of inertia bone receivers.

The above described equipment, in spite of some limitations, has proved to be a useful and powerful laboratory tool. The setups shown in Figures 5 and 6 permit the rapid taking of consistently reproducible response curves.

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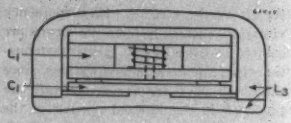


Figure 1. Construction of inertia unit

L_1—electromagnet structure
C_1—spring
L_3—housing

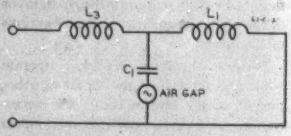


Figure 2. Equivalent electric circuit for structure shown in Figure 1

ture is surrounded by a housing, indicated schematically in Figure 1 as L_3. The equivalent electric circuit is represented in Figure 2, where the same symbols are used as in Figure 1 to designate the respective equivalent components.

The voltage produced across the magnet coil is proportional to the air gap velocity. It can be shown that the velocity I_1 of the air gap bears the following relationship to the velocity, I, imparted to the housing L_3 by external forces:

$$I_1 = Ix \frac{(f/f_o)^2}{1-(f/f_o)^2} \qquad (1)$$

where f_o is the resonant frequency of the vibrating system formed by the spring C_1 and electromagnet L_1, while f is the frequency of the force applied to the housing. For frequencies below resonance where f/f_o is small, the formula then can be written:

$$I_1 = Ix\ (f/f_o)^2 \qquad (2)$$

Equation 2 shows the air gap velocity to be proportional to the square of the applied frequency at frequencies below resonance. Therefore, magnetic or dynamic microphones will have a frequency discrimination of 12 decibels per octave in this range. In contrast, crystal or carbon microphones, in which voltage is proportional to the displacement, will have a frequency discrimination of only 6 decibels per octave. This result illustrates the advantage of the inertia magnetic throat microphone over the other types on account of its greater ability to discriminate against low frequencies.

It thus is seen that the rapidly rising response characteristic of the magnetic inertia throat microphone, below the resonant frequency, effectively compensates for the frequency distortion generated in the throat. In order to obtain satisfactory intelligibility, it is desirable to set the resonant frequency of the microphone at a relatively high value, in the neighborhood of 3,000 to 4,000 cycles. On the other hand, though such high frequency inertia throat microphones give a very good intelligibility when used with standard flat-response amplifiers, their output is low. The output can be increased substantially by lowering the resonant frequency to about 1,000 cycles, but this is accomplished at the expense of intelligibility.

Despite this difficulty, there are many applications which require that the two conflicting requirements of high sensitivity and high intelligibility be satisfied simultaneously, for example, in the case of sound powered communication systems. Through the addition of a second resonant frequency to a low frequency microphone system (approximately 1,000 cycles) a substantial extension of the sensitivity of the throat microphone can be obtained without loss of intelligibility. This second frequency is obtained by incorporating in its mechanical system a second mass and compliance system, having its resonant frequency somewhere in the range between 2,500 and 4,000 cycles. Such double resonant microphones have then a substantial output over the entire range from 1,000 to 3,000 or 4,000 cycles.

Figure 3 shows a schematic layout of a

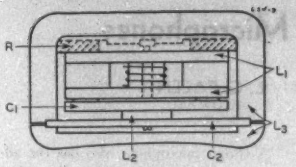


Figure 3. Construction of double resonant inertia unit

L_1—electromagnet structure
L_2—coupler
L_3—housing
C_1—spring of single resonant unit
C_2—spring for second resonance

double resonant electromagnetic inertia system. Here L_1 is the mass of the electromagnet, supported by the spring C_1 in the same fashion as shown in Figure 1. Springs C_1, C_2, and coupler of mass L_2 form the second resonant system. C_2 is connected to the spring C_1 through L_2. All parts shown in Figure 3 also are shown in the exploded Figure 4 and are designated by the same symbols. The spring C_2 is held inside a frame structure, which is necessary to facilitate the mounting of the spring inside the housing. Use of the frame structure also reduces the losses in C_2 and provides means for easy duplication of spring properties in production. Figure 5 represents the equivalent electric circuit and uses the same symbols as in Figures 3 and 4 to designate the respective equivalent components. The electromagnet L_1 is connected to the housing L_3 through a mechanical transmission system, consisting of the springs C_1 and C_2, and the interposed mass L_2. This transmission system transmits the imparted velocity to the air gap formed between L_1 and C_1 with an efficiency which increases with frequency, thus permitting emphasis on the high frequencies at the expense of the low.

Of the two resonant frequencies incorporated in this system, one is represented approximately by the system consisting of the mass L_1 and the spring C_1. The second resonance, that of the system consisting of the two springs C_1 and C_2 and the mass L_2, is considerably higher than the first one. At frequencies above the second resonance most of the velocity imparted into the housing is absorbed by the spring C_1, and only a small fraction of it can be transmitted to the air gap. This results in a relatively sharp cutoff at

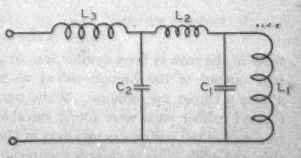


Figure 5. Equivalent electric circuit for structure shown in Figures 3 and 4

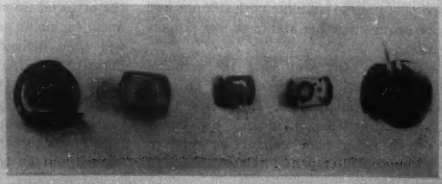


Figure 4. Exploded view of parts comprising a double resonant unit

higher frequencies and a band pass character for this type of throat microphone. The sharp cutting off of frequencies outside the range required for intelligibility is desirable, as it prevents transmission of high frequency noises and static and thus contributes to the improvement of intelligibility.

The values of the two resonant frequencies are obtained by solving the characteristic determinant of the equivalent circuit of Figure 5. Equation 3 is the solution for the two resonant frequencies with $\omega = 2\pi f$.

$$\omega^2 = \frac{1}{2}\frac{1}{L_1C_1}\left(\frac{L_1C_1}{L_2C_2}+\frac{L_1C_1}{L_2C_3}+1+\frac{L_1}{L_2}\right) \mp \frac{1}{L_1C_1}\left[\left(\frac{L_1C_1}{L_2C_2}+\frac{L_1C_1}{L_2C_3}-1+\frac{L_1}{L_2}\right)^2+4\frac{L_1^2}{L_2^2}\frac{C_1}{C_2}\right]^{1/2} \quad (3)$$

By expanding the square root expression and retaining the first two terms only, the following simplified approximate equations are obtained:

$$\omega_1^2 = \frac{1}{C_1}\left(\frac{1}{L_1}+\frac{1}{L_2}\right)-\delta = \omega_{10}^2-\delta \quad (4)$$

$$\omega_2^2 = \frac{1}{C_2}\left(\frac{1}{L_2}+\frac{1}{L_2}\right)+\delta = \omega_{20}^2+\delta \quad (5)$$

where

$$\delta = \frac{1}{L_2^2C_1C_2(\omega_{20}^2-\omega_{10}^2)}$$

The foregoing expansion is valid only when the difference $\omega_{20}^2-\omega_{10}^2$ is large, so that the correction term δ is small compared with both ω_{10}^2 and ω_{20}^2. ω_{10} and ω_{20} correspond roughly to the two resonance frequencies of the system.

For experimental purposes, as well as for different applications, it is desirable to build models having different spreads between the two resonant frequencies. This can be accomplished by changing some or all of the parameters in equations 4 and 5. On the other hand, the values of certain components remain more or less fixed on account of limitations in size, as well as the need to obtain optimum efficiency within a given volume. Among the fixed values are L_1 and C_1, which form the electromagnetic system, as well as the value of L_2, which is the mass of the housing.

Equations 4 and 5 demonstrate that, even if the values L_1, C_1, and L_2 are kept fixed, it is still possible to obtain wide variations in the value of the frequency f_2 by simply changing L_2 and C_2. It is further seen by inspecting equation 3 that the frequencies f_1 and f_2 are functions of

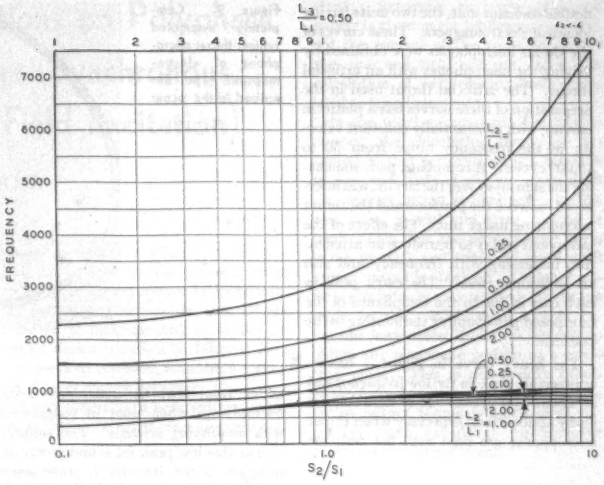


Figure 6. Curves showing relation of frequencies f_1 and f_2 as functions of the ratio $S_2 \div S_1$ plotted for various values of $L_2 \div L_1$

Curves computed for $L_3 \div L_1 = 0.50$

the two ratios: $L_2 \div L_1$ and $C_1 \div C_2$.

It is therefore possible to plot families of curves for the two frequencies as functions, for example, of the ratio C_1/C_2, the different curves corresponding to different values of L_2/L_1. Such curves, as calculated from equation 3, are shown in Figure 6. In this figure the values for f_1 form the lower family of curves, which fall closely together, as is to be expected from equation 4, where L_1 and C_1 remain fixed. On the other hand the values for f_2 show a wide spread, since as shown in equation 5 both C_2 and L_2 are variables. The curves in Figure 6 therefore can be used to construct throat microphones with different properties. The curves were computed for: $L_3 \div L_1 = 0.50$.

It is desirable sometimes to build electromagnetic transducers having an extremely narrow band of response. For example, in bridge circuits the null position must be determined very sharply for the frequency of the power source to which such a bridge is connected and for the elimination of the disturbing effect of harmonics present in the source due to unavoidable distortion. In this case it is important to have a detector which will be sensitive only to the frequency of the fundamental component of the current wave. Here equations 4 and 5 become invalid, as the difference $\omega_{20}^2-\omega_{10}^2$ becomes very small, hence δ very large.

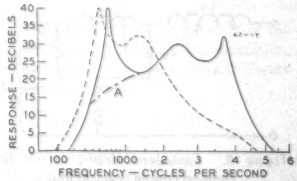


Figure 7. Comparative response curves for single and double resonant units

------ Single resonance unit
——— Double resonance unit
— — — Effect of damping on double resonant unit (high articulation)
A—High articulation unit

The complete equation 3 consequently must be used. For example, by using the values $L_2 \div L_1 = 1$ and $C_1 \div C_2 = 1$, response in the narrow band from approximately 800 to 1,250 cycles is obtained (Figure 6). Such a unit, when used as a detector (receiver), will permit very sharp balancing of a 1,000-cycle bridge.

Throat microphones built with components as illustrated in Figure 4 and having response in the band between 1,000 and 4,000 cycles have given high intelligibility scores when used as a sound powered microphone in conjunction with sound powered receivers.

In Figure 7 comparative response curves of single and double resonant units are shown. The light curve represents the response of a single resonant unit, and the heavy curve represents that of a

double resonant unit, the two units having identical electromagnets. These curves of the throat microphones were obtained by driving the microphones with an artificial throat. The artificial throat used in the preparation of these curves has a platform moving with substantially constant velocity in the frequency range from 50 to 10,000 cycles. A compliant pad, simulating the skin layer over the larynx, was interposed between the platform and the throat microphone under test. The effect of the interposed pad is to introduce an attenuation increasing with frequency and also an additional peak. The extra peak in each case is due to the compliance of the interposed pad coupling the housing to the platform.

The heavy curve in Figure 7 has an appreciable peak on the low frequency end at about 800 cycles. It is desirable for many applications, especially when throat microphones are used with flat response

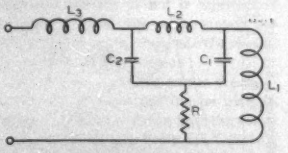
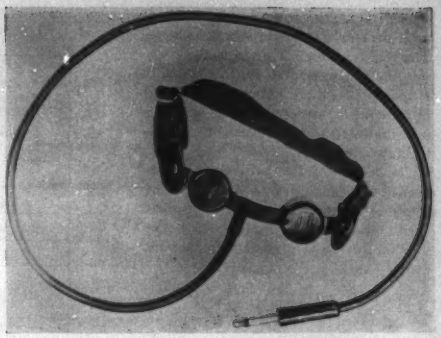


Figure 8. Equivalent electric circuit for damped double resonant unit

amplifying systems, to reduce or eliminate this peak in order to improve still further the intelligibility of such communication systems. This is done by introducing a damping member between the electromagnet L_1 and the housing L_3, as indicated schematically by the dotted lines in Figure 3. The equivalent electric circuit is shown in Figure 8. Placing the resistor R in the position shown in Figure 8 permits a very effective damping of the low frequency peak without affecting essentially the performance of such throat microphones in the neighborhood of the high frequency resonance. This is true since the damping resistance R effectively can suppress oscillations set up in the mesh, consisting of L_1, C_1, and R. On the other hand, high frequency oscillations set up in the mesh L_2, C_1, and C_2 are affected only a little by the energy absorbing resistance R, since any transfer of energy from this mesh must take place through the high impedance path L_1 in order to reach R. The dotted line in Figure 7 represents the response of a damped double resonance throat microphone. The articulation of these microphones is

Figure 9. Completely assembled typical throat microphone of electromagnetic type described in the paper



better than that of undamped throat microphones when used in conjunction with amplifying systems. The suppression of this low peak for sound power application is not important, since sound powered receivers can be built to have a somewhat attenuated response in the range corresponding to the low frequency peak of the throat microphone. The loss of sensitivity caused by the introduction of damping is not serious, as these microphones are used with amplifying systems. Damping can be obtained by using different damping materials introduced into the mechanical system, in the manner indicated in Figure 3. Best results were obtained by using a damping cup containing oil. Oil damping cups have the advantage of containing little stiffness as compared with the amount of resistance they introduce. The introduction of damping reduces to some extent the sharp cutoff characteristic of the undamped unit. The average output of a sound power throat microphone wound for 100-ohm internal impedance is approximately 15 millivolts, whereas the output of a similar high articulation throat microphone is on the average of 2 millivolts.

It is obvious that other parts of the head, such as cheeks, jaw, temple, vibrate under the influence of sounds produced in the mouth cavity and can be used to actuate such contact microphones. Especially good results are obtained when placing the throat microphone on the lips.

Figure 9 is a photograph of a typical throat microphone. This instrument consists of two units, disposed symmetrically on both sides of the throat. They are

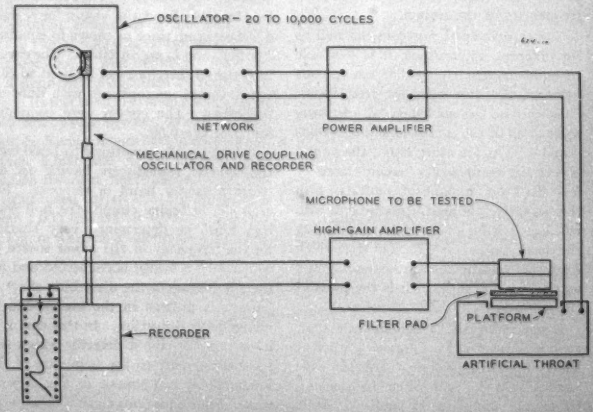


Figure 10. Experimental setup for automatically recording frequency response of throat microphone driven by artificial throat

Performance Calculations on Polyphase Reluctance Motors (Synchronous Motors Without Field Excitation)

P. H. TRICKEY
MEMBER AIEE

IN 1926, Messrs. Doherty and Nickle presented their classic paper on "Synchronous Machines" giving a complete and thorough analysis. Since many fractional horsepower engineers have occasion to design small reluctance motors (synchronous motors without field excitation) and these engineers in general have no need of becoming thoroughly familiar with the great and extensive field of synchronous motor theory, it has seemed advisable to simplify the equations from this famous paper by eliminating the terms having to do with field current and to arrange them in the form of a simple calculation sheet. It also has been found possible by the use of calculated curves to arrange a simple method of calculating the synchronous pull-out torque.

As in the case of induction motors, it is customary also in synchronous motor engineering to divide the work of designing a unit into three parts, first, choosing trial dimensions and windings, second, calculating the motor "constants" such as resistances, reactances, and iron loss and third, calculating the performance of the trial design. If the performance is not satisfactory further trial designs are made and the same procedure followed.

In the case of the first step, the experienced designer can often make the first trial very close to the correct design either from his experience or from making ratios from similar designs. If the designer is inexperienced or if the required design is radically different from any previous machine, sometimes a number of trials may be necessary.

Many papers have been written on the second step, the calculation of motor constants. Reference to some of these papers is given in the bibliography. It is not the purpose of this paper to discuss step one and two, but step three, the calculation of performance from calculated or tested constants.

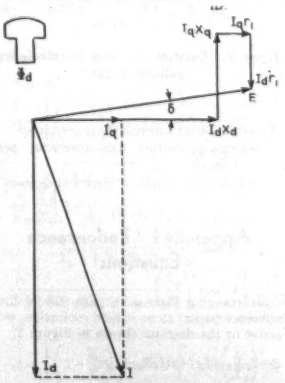


Figure 1. Vector diagram of reluctance motor

In the usual calculations of induction motors, the calculation forms are arranged so that performance is a function of slip, and trials of slip are made until the desired output is obtained. In this case, also, a trial and error method is used. This time the displacement angle is the variable and trials are made until proper output is obtained. On large machines, it is fairly easy to check the torque angle by test. With small motors below one horsepower it often is difficult to obtain the zero angle positon as a reference point. This is not greatly disadvantageous, however, as the performance versus output torque is much more important, and calculated displacement angles are usually sufficient.

Performance Equations

Rearranging Figure 20, page 925 of the reference paper,[1] to omit field excitation, we arrive at the diagram shown in Figure 1 and the equation below.

$$E = I_d X_d + I_q r_1 + j(I_q X_q - I_d r_1)$$

Solving for I_d and I_q,

$$I_d = \frac{E}{X_d} \frac{1}{1+(r_1/X_q)(r_1/X_d)} \times \left(\cos\delta - \frac{r_1}{X_q}\sin\delta\right)$$

$$I_q = \frac{E}{X_d} \frac{1}{1+(r_1/X_q)(r_1/X_d)} \times \left(\frac{1}{X_q/X_d}\sin\delta + \frac{r_1}{X_q}\cos\delta\right)$$

Line current

$$I = \sqrt{I_q^2 + I_d^2}$$

Power input

$$P = ph\,E\,(I_q\cos\delta - I_d\sin\delta)$$

Output

$$\text{Output} = \text{input} - (\text{Iron loss} + \text{friction} + \text{windage} + ph\,I^2 r_1)$$

Torque

$$T = \frac{112.7}{Syn}\ \text{output (in ounce feet)}$$

held on the throat by means of an elastic band, which is adjustable to control the pressure on the throat. As seen in the illustration, the instrument is provided with a standard cord and plug.

Figure 10 is a schematic diagram of the setup used in testing throat microphones. It consists of an oscillator mechanically coupled to a sound level recorder. The oscillator feeds a signal with continuously variable frequency through a network into a linear power amplifier. The power amplifier in turn drives an artificial throat whose platform vibrates with an essentially constant velocity in the frequency range of 50 cycles to 10,000 cycles. The throat microphone is placed on the vibrating platform with a filter pad interposed between the microphone and the platform. The purpose of the filter pad is to simulate as far as possible the layer of skin covering the larynx of an average speaker. The output of the throat microphone is amplified by a high gain amplifier and fed into the sound level recorder. Thus an automatic record is obtained of the variation of the output as a function of the frequency applied to the microphone.

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Synchronous Pull-Out Torque

The maximum torque that the motor will develop while in synchronism, known as "pull-out" torque, may be obtained as follows:

$T = (112.7/Syn)$ output $= (112.7/Syn)$ (input − losses)

$T = (112.7/Syn)$ [(input − copper loss) − $(Fe + F + W)$]

$T = (112.7/Syn)$ $[P_1 - (Fe + F + W)]$

Since iron loss, friction, and windage are essentially constant at synchronous speed, the maximum synchronous torque will occur when P_1 is at its maximum value. By substituting the current values given above in the equations for input and copper loss, it can be shown that

$$P_1 = ph\,\frac{E^2}{X_d}\,\frac{1}{1+(r_1/X_q)(r_1/X_d)}\,A$$

Where A is a rather cumbersome group of terms containing r_1, X_q, X_d, and δ.

Values of A maximum have been calculated and plotted in Figure 2, so that we find it fairly easy to calculate the synchronous pull-out torque.

$$T_{PO} = \frac{112.7}{Syn}\,[ph\,E\,M_1\,A_m - (Fe + F + W)]$$

(ounce-feet)

Where $M_1 = \dfrac{E}{X_d}\,\dfrac{1}{1+(r_1/X_q)(r_1/X_d)}$

It can easily be seen from Figure 2 how important it is to keep r_1/X_q and r_1/X_d as small as possible.

Figure 3 shows a form which has been arranged to make these calculations as simple as possible. The displacement angle δ is assumed and the performance values calculated. Items 23 to 27 are only in calculating the pull-out torque.

Since reluctance motors are usually less than one horsepower, Figure 3 has been arranged in terms of actual values of volts, amperes, and ohms, instead of "per unit" values which are seldom used by fractional horsepower motor engineers.

List of Symbols

E = volts per phase
$F+W$ = friction plus windage
Fe = iron loss
I = current per phase
I_d = current in direct axis
I_q = current in quadrature axis
ph = number of phases
P = power input in watts
r_1 = primary resistance per phase
Syn = synchronous rpm
T = torque in ounce-feet
T_{PI} = synchronous pull-in torque
T_{PO} = synchronous pull-out torque

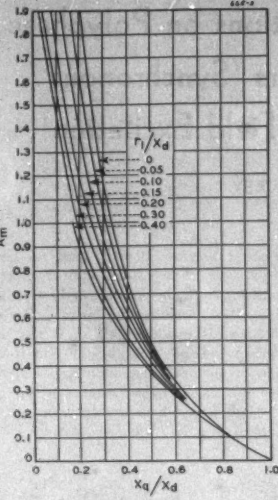

Figure 2. Constant A_m used in calculating pull-out torque

X_d = total direct axis reactance per phase
X_q = total quadrature axis reactance per phase
δ = displacement angle in electrical degrees

Appendix I. Performance Equations

Rearranging Figure 20, page 925 of the reference paper[1] to omit field excitation, we arrive at the diagram shown in Figure 1.

$E = I_d X_d + I_q r_1 + j(I_q X_q - I_d r_1)$

$E\cos\delta = I_d X_d + I_q r_1$ and $E\sin\delta = I_q X_q - I_d r_1$

Solving for I_d

$EX_q\cos\delta = I_d X_d X_q + I_q X_q r_1$ and
$Er_1\sin\delta = -I_d r_1^2 + I_q X_q r_1$
$E(X_q\cos\delta - r_1\sin\delta) = I_d(X_q X_d + r_1^2)$

$$I_d = E\,\frac{1}{r_1^2 + X_q X_d}\,(X_q\cos\delta - r_1\sin\delta) = \frac{E}{X_d}\,\frac{1}{1+(r_1/X_q)(r_1/X_d)}\left(\cos\delta - \frac{r_1}{X_q}\sin\delta\right)$$

Solving for I_q

$Er_1\cos\delta = I_d X_d r_1 + I_q r_1^2$, and
$EX_d\sin\delta = -I_d X_d r_1 + I_q X_q X_d$
$E(X_d\sin\delta + r_1\cos\delta) = I_q(r_1^2 + X_q X_d)$

$$I_q = E\,\frac{1}{r_1^2 + X_q X_d}\,X_d\sin\delta + r_1\cos\delta = \frac{E}{X_d}\,\frac{1}{1+(r_1/X_q)(r_1/X_d)}\left(\frac{\sin\delta}{X_q/X_d} + \frac{r_1}{X_q}\cos\delta\right)$$

Line current $I = \sqrt{I_d^2 + I_q^2}$

	E	127		
	X_d	\179		
	X_q	51.8		
	r_1	6.76		
	r_1/X_d	0.0378		
	r_1/X_q	0.1306		
	X_q/X_d	0.290		
	$(r_1/X_d)(r_1/X_q)$	0.00494		
	$1+(r_1/X_d)(r_1/X_q)$	1.005		
	$M_1 = \frac{E}{X_d}\,\frac{1}{1+(r_1/X_d)(r_1/X_q)}$	0.705		
1	δ (IN ELEC. DEG.)	5	15	
2	COS δ	0.996	0.966	
3	(r_1/X_q) SIN δ	0.0114	0.0338	
4	(2) − (3)	0.985	0.932	
5	$I_d = M_1 \times (4)$	0.695	0.657	
6	$\left[1/(X_q/X_d)\right]$ SIN δ	0.300	0.893	
7	(r_1/X_q) COS δ	0.130	0.126	
8	(6) + (7)	0.430	1.019	
9	$I_q = M_1 \times (8)$	0.303	0.718	
10	$I = \sqrt{I_d^2 + I_q^2}$	0.758	0.973	
11	I_q COS δ	0.302	0.694	
12	I_d SIN δ	0.061	0.170	
13	(11) − (12)	0.241	0.524	
14	INPUT = ph E (13)	92.0	199	
15	$I^2 r_1$ ph	11.6	19.2	
16	F_e LOSS	21.7	21.7	
17	F + W	5.8	5.8	
18	LOSSES = (15) + (16) + (17)	39.1	46.7	
19	OUTPUT = (14) − (18)	52.9	152.3	
20	TORQUE = $\frac{112.7}{SYN}$ (19)	3.31	9.5	
21	EFF = (19)/(14)	57.5	76.6	
22	P.F. = (13)/(10)	31.8	53.9	
23	HORSEPOWER	0.0708	0.203	
24	Am (FROM FIG. 2)			1.130
25	$P_{1\,MAX} = ph\,E\,M_1\,A_m$			303
26	$F_e + F + W = (16) + (17)$			28
27	(25) − (26)			275
28	$T_{PO} = \frac{112.7}{SYN}$ (27)			17.2

Figure 3. Calculation sheet for reluctance motors

Power input $P = ph\,E\,I_q\cos\delta - ph\,EI_d\sin\delta$
$P = ph\,E\,(I_q\cos\delta - I_d\sin\delta)$
Total losses $L = Fe + F + W + ph\,I^2 r_1$
Output = input − losses
Torque = $(112.7/Syn)$ output (in ounce-feet)
Efficiency = Output/input
Power factor = Input/$ph\,E\,I$

Appendix II. Pull-Out Torque or Maximum Synchronous Torque

$T = (112.7/Syn)$ output $= (112.7/Syn)$ (input − losses)

$T = (112.7/Syn)$ [(input − copper loss) − $(Fe + F + W)$]

$T = (112.7/Syn)$ $[P_1 - (Fe + F + W)]$

Since the iron loss, friction, and windage are essentially constant at synchronous speed, the maximum synchronous torque will occur when P_1 is at its maximum value. Power input in terms of δ power input

$P = ph\,E\,(I_q\cos\delta - I_d\sin\delta)$

$$P = ph\,E\left\{\frac{E}{X_d}\frac{1}{1+(r_1/X_q)(r_1/X_d)}\left(\sin\delta\cos\delta+\frac{r_1}{X_q}\frac{X_q}{X_d}\cos^2\delta\right)-\frac{E}{X_d}\frac{1}{1+(r_1/X_q)(r_1/X_d)}\times\left(\frac{X_q}{X_d}\sin\delta\cos\delta-\frac{r_1}{X_q}\frac{X_q}{X_d}\sin^2\delta\right)\right\}\frac{1}{X_q/X_d}$$

$$\text{Input } P = ph\frac{E^2}{X_d}\frac{1}{1+(r_1/X_q)(r_1/X_d)}\times\left\{\left(1-\frac{X_q}{X_d}\right)\sin\delta\cos\delta+\frac{r_1}{X_q}\frac{X_q}{X_d}\right\}\frac{1}{X_q/X_d}$$

Copper loss in terms of δ

Copper loss $= ph\,I^2\,r_1, \quad I^2 = I_d^2 + I_q^2$

Thus,

$$\text{Copper loss} = ph\,r_1(I_d^2+I_q^2)$$

$$\text{Copper loss} = ph\,r_1\left(\frac{E}{X_q}\frac{1}{1+(r_1/X_q)(r_1/X_d)}\right)^2\left\{\left(\frac{X_q}{X_d}\cos\delta-\frac{r_1}{X_q}\frac{X_q}{X_q}\sin\delta\right)^2+\left(\sin\delta+\frac{r'\,X_q}{X_q\,X_d}\cos\delta\right)^2\right\}$$

$$\text{Copper loss} = \frac{ph\,E^2}{X_q}\frac{1}{1+(r_1/X_q)(r_1/X_d)}\times\left(\frac{r_1}{X_q}\frac{1}{1+(r_1/X_q)(r_1/X_d)}\right)\left\{\left(\frac{X_q}{X_d}\cos\delta-\frac{r_1X_q}{X_qX_d}\times\sin\delta\right)^2+\left(\sin\delta+\frac{r_1}{X_q}\frac{X_q}{X_d}\cos\delta\right)^2\right\}$$

$$\text{Copper loss} = \frac{ph\,E^2}{X_q}\frac{1}{1+(r_1/X_q)(r_1/X_d)}\times\left(\frac{r_1}{X_q}\frac{1}{1+(r_1/X_q)(r_1/X_d)}\right)\times\left\{\left(\frac{X_q}{X_d}\right)^2\cos^2\delta-2\frac{r_1}{X_q}\left(\frac{X_q}{X_d}\right)^2\sin\delta\cos\delta+\left(\frac{r_1}{X_q}\right)^2\left(\frac{X_q}{X_d}\right)^2\sin^2\delta+\sin^2\delta+2\times\frac{r_1}{X_q}\frac{X_q}{X_d}\sin\delta\cos\delta+\left(\frac{r_1}{X_q}\frac{X_q}{X_d}\right)^2\cos^2\delta\right\}$$

$$\text{Copper loss} = \frac{ph\,E^2}{X_d}\frac{1}{1+(r_1/X_q)(r_1/X_d)}\times\left(\frac{r_1}{X_q}\frac{1}{1+(r_1/X_q)(r_1/X_d)}\right)\times\left\{\sin^2\delta+\left(\frac{X_q}{X_d}\right)^2\cos^2\delta+\left(\frac{r_1}{X_q}\right)^2\left(\frac{X_q}{X_d}\right)^2+2\frac{r_1}{X_q}\frac{X_q}{X_d}\left(1-\frac{X_q}{X_d}\right)\sin\delta\cos\delta\right\}\frac{1}{X_q/X_d}$$

Power input − copper loss $= P_1$

$$P_1 = \frac{ph\,E^2}{X_d}\frac{1}{1+(r_1/X_q)(r_1/X_d)}\times\left\{\left(1-\frac{X_q}{X_d}\right)\sin\delta\cos\delta+\frac{r_1}{X_q}\frac{X_q}{X_d}-\frac{r_1}{X_q}\frac{1}{1+(r_1/X_q)(r_1/X_d)}\left[\sin^2\delta-\left(\frac{X_q}{X_d}\right)^2\cos^2\delta+\left(\frac{r_1}{X_q}\frac{X_q}{X_d}\right)^2+2\frac{r_1}{X_q}\frac{X_q}{X_d}\left(1-\frac{X}{X_d}\right)\sin\delta\cos\delta\right]\right\}\frac{1}{X_q/X_d}$$

$$P_1 = ph\frac{E^2}{X_d}\frac{1}{1+(r_1/X_q)(r_1/X_d)}A$$

Output = (power input − copper loss) − ($Fe+F+W$)

Output $= P_1 - (Fe+F+W)$

Torque $= (112.7/Syn)\,[P_1-(Fe+F+W)]$

Maximum or pull-out torque will occur when P_1 is maximum. $P_{1\max}$ will occur when A is maximum. Thus

$$T_{PO} = (112.7/Syn)\,[P_{1\max}-(Fe+F+W)]$$

$$P_{1\max} = \frac{ph\,E^2}{X_d}\frac{1}{1+(r_1/X_q)(r_1/X_d)}A_m$$

$$P_{1\max} = ph\,E\,M_1A_m$$

Where

$$A = \left\{\left(1-\frac{X_q}{X_d}\right)\sin\delta\cos\delta\left[1-\frac{r_1}{X_q}\times\frac{1}{1+(r_1/X_q)(r_1/X_d)}2\frac{r_1}{X_q}\frac{X_q}{X_d}\right]+\frac{r_1}{X_q}\frac{X_q}{X_d}\left[1-\frac{r_1}{X_q}\frac{1}{1+(r_1/X_q)(r_1/X_d)}\frac{r_1}{X_q}\frac{X_q}{X_d}\right]-\frac{r_1}{X_q}\frac{1}{1+(r_1/X_q)(r_1/X_d)}\sin^2\delta-\frac{r_1}{X_q}\frac{1}{1+(r_1/X_q)(r_1/X_d)}\left(\frac{X_q}{X_d}\right)^2\cos^2\delta\right\}\frac{1}{X_q/X_d}$$

or

$$A = \left\{\left(1-\frac{X_q}{X_d}\right)\sin\delta\cos\delta\left[1-2\left(\frac{r_1}{X_d}\right)^2\times\frac{1}{X_q/X_d}\frac{1}{1+(r_1/X_d)^2 1/(X_q/X_d)}\right]+\frac{r_1}{X_d}\left[1-\left(\frac{r_1}{X_d}\right)^2\frac{1}{X_q/X_d}\times\frac{1}{1+(r_1/X_d)^2 1/(X_q/X_d)}\right]-\frac{r_1}{X_d}\frac{1}{X_q/X_d}\times\frac{1}{1+(r_1/X_d)^2 1/(X_q/X_d)}\sin^2\delta-\frac{r_1}{X_d}\frac{X_q}{X_d}\frac{1}{1+(r_1/X_d)^2 1/(X_q/X_d)}\cos^2\delta\right\}\frac{1}{X_q/X_d}$$

Let

$$B = \frac{r_1}{X_d}\frac{1}{X_q/X_d}\frac{1}{1+(r_1/X_d)^2 1/(X_q/X_d)}$$

then

$$A = \left\{\left(1-\frac{X_q}{X_d}\right)\sin\delta\cos\delta\left[1-2\frac{r_1}{X_d}B\right]+\frac{r_1}{X_d}\left[1-\frac{r_1}{X_d}B\right]-B\sin^2\delta-B\left(\frac{X_q}{X_d}\right)^2\cos^2\delta\right\}\frac{1}{X_q/X_d}$$

$$A = \left(1-2\frac{r_1}{X_d}B\right)\frac{1}{X_q/X_d}\times\left(1-\frac{X_q}{X_d}\right)\sin\delta\cos^2\delta-B\left(\frac{1}{X_q/X_d}\sin^2\delta+\frac{X_q}{X_d}\cos^2\delta-1\right)$$

The maximum value of A against δ as the variable has been plotted in Figure 2 for different values of X_q/X_d and r_1/X_d.

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Governor for Variable-Ratio Transmission Used in Developmental 400-Cycle Electric System for Large Aircraft

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Synopsis: A prerequisite for the successful parallel operation of main engine driven a-c generators is a suitable infinitely variable-ratio transmission and high speed governor to control it. This paper describes the development of such a governor and its successful operation on a developmental two-generator 400-cycle a-c system.

THE TREND of certain types of military and civil aircraft toward larger airplanes requiring large amounts of electric power, demanded equally revolutionary thinking in the field of aircraft electrical engineering. Much thought and discussion[1,2] in recent years has been given to an a-c system which would have the generators driven by the main engines and operating in parallel, which with proper controls makes possible improved continuity of service.[3] Flight conditions may demand more than a 3 to 1 speed range of the main engines, and all engines would not necessarily operate at the same speed throughout one flight. With such conditions it is essential that some form of variable ratio transmission be coupled between each prime mover and generator, so that a parallel system at substantially constant frequency is practical. Variation in the ratio of each transmission would have to be automatic, to maintain each generator speed within the range required in spite of high acceleration and wide speed differences of the prime movers. An electric governor which maintained successful parallel operation of the generators and equality of load division under various conditions of acceleration and loading was developed. Design data and performance characteristics of this governor are presented in the following.

Conclusions

Approximately 200 hours of operating experience have been gained on the developmental 400-cycle a-c two-generator system, and governor operation has been satisfactory throughout. Under both steady state and transient conditions the governor and its attendant load-frequency droop circuit have performed their required functions well. Although load division with values of no-load to full-load linear droop of less than 5 per cent was generally satisfactory, the system performance was at times erratic. A linear frequency droop from no-load to full-load of 5 per cent was found to be eminently satisfactory, and this value was adopted for all remaining tests on the two generator system.

The speed of response of the governor was good. With the generators operating in parallel, and one prime mover accelerated or decelerated, the governor responded to begin to restore initial conditions before the end of the acceleration or deceleration period.

In general, movement of the governor servomechanism began 0.008 second after inception by the control coil of the signal demanding governor response. On the equivalent of an unloaded system the effective gear ratio of the variable-ratio transmission was changed from 2:1 to 1.3:1 in 0.18 second and vice versa. Since the speed changes were brought about by a unit function change in signal voltage, the simulated acceleration approached an infinite value.

Tests on a four-generator system have not yet been made, but it is hoped to begin these, together with preliminary flight tests, in the near future.

The weight of the governor pilot valve and solenoid assembly is approximately 8 pounds; the weight of the junction box containing the control and droop circuits is approximately 5 pounds; in an aircraft installation the piston assembly is part of the variable-ratio transmission.

The governor, together with the variable-ratio transmission which it controls, and attendant electric apparatus have combined to make an a-c system with parallel operated generators practical for use on large aircraft of the future. Operation of a developmental two-generator system over a period of several months and under varying conditions has been very satisfactory. It is hoped that in the near future planned flight tests will prove further the value of a-c systems for aircraft auxiliary apparatus.

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Governor Requirements

The governor design and performance requirements were set up to meet the most extreme operating conditions thought possible on airplanes which require a-c accessory power. Calculations based upon the application of rated engine torque to the propeller inertia of the engine–propeller combination indicated a possible acceleration at the engine drive pad of 2,150 rpm per second. Though in practice accelerations will probably be less than this, the governor was designed to maintain parallel operation with one engine accelerated at this rate while the speed of the others remained constant. Some of the essential features of the performance requirements are that the governor be designed to operate from sea level to 40,000 feet with ambient temperature variations from −55 degrees centigrade to +60 degrees centigrade, under humid or dusty conditions with specified linear and torsional vibrations. More particularly, requirements affecting the operational design of the governor are set out as in Table I. With these conditions arising from the design of the variable ratio transmission, the governor was required

Table I. Performance Requirements of Governor

Item	Characteristic	Governor Requirement
1.	Input speed range to variable-ratio transmission	2,100–9,000 rpm
2.	Output speed of generator	6,000 rpm
3.	Speed of governor tachometer shaft for generator speed of 6,000 rpm	3,000 rpm
4.	Maximum overdrive ratio of variable-ratio transmission	2.85
5.	Maximum underdrive ratio of variable-ratio transmission	0.67
6.	Total stroke of governor tie rod	1.25 inches
7.	Oil pressure available for governor	250 pounds per square inch
8.	Force on governor tie rod	See Figure 1
9.	Tie rod speed at maximum acceleration (2,150 rpm per second at engine). Maximum overdrive	3.5 inches per second
10.	Tie rod speed at maximum acceleration (2,150 rpm per second at engine). Maximum underdrive	0.5 inch per second
11.	Maximum time for tie rod to reach required velocity	0.03 second

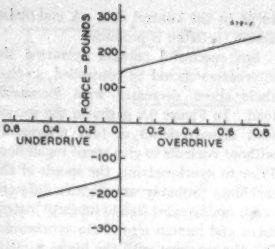


Figure 1. Curve of force on tie rod of governor servomechanism

to permit satisfactory parallel operation of the alternators under specified operating conditions with possible engine accelerations of 2,150 rpm per second. To assist in obtaining successful parallel operation of the generators an electric circuit was required which would admit of a decrease in generator speed with increasing load. Thus over the expected engine speed range of 700 rpm to 3,000 rpm, which with the step-up gear becomes 2,100 rpm to 9,000 rpm at the variable-ratio transmission, the governor was required to hold speed as follows:

Alternator Load, Kw	Speed, Rpm	Tolerance, Per Cent
0	6,300 (105 per cent)	±1
30 (100 per cent)	6,000 (100 per cent)	±1
45 (150 per cent)	5,850 (97.5 per cent)	±1
60 (200 per cent)	5,700 (95 per cent)	±1

In accordance with general aircraft practice the governor and its control circuits were required to be of minimum weight and to occupy a minimum of space in meeting all requirements.

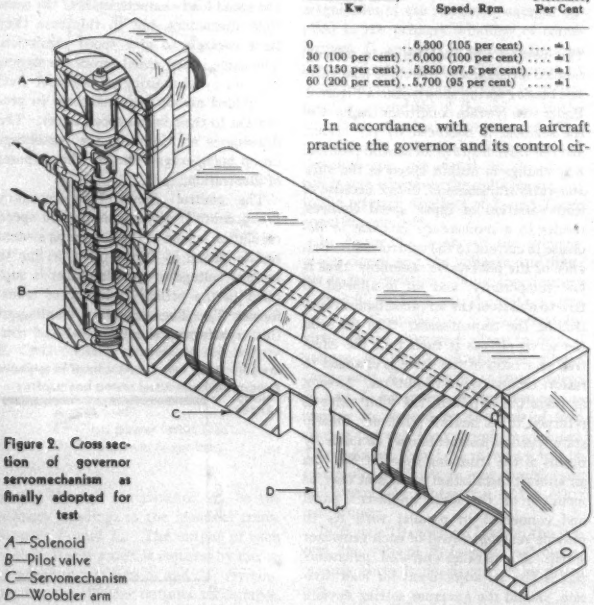


Figure 2. Cross section of governor servomechanism as finally adopted for test

A—Solenoid
B—Pilot valve
C—Servomechanism
D—Wobbler arm

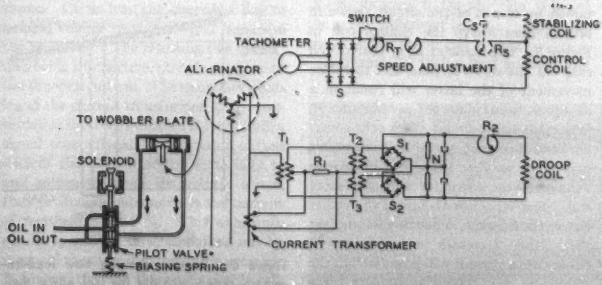


Figure 3. Schematic diagram of governor and control circuits

Design Data for Solenoid and Pilot-Valve Assembly

The governor is essentially a constant speed device. To provide suitable load division among the generators a characteristic is added to each governor which produces a 5 per cent decrease in system frequency when the generators are delivering full load. This droop circuit is independent of the actual governing circuits and therefore need not be considered in the design of the solenoid and pilot-valve assembly.

An isometric view of the governor assembly, as finally adopted for test, is shown in Figure 2 and a schematic diagram in Figure 3. Under steady state conditions the pilot valve is balanced in its mid-position against the force of a solenoid magnet by means of a biasing spring. A momentary change in current to the solenoid (because of a momentary change in output speed of the transmission) results in temporary unbalance, and oil is allowed to flow to the servomechanism until the condition is corrected. This correction must be very rapid to provide reasonably good load division among generators during engine speed transients. The pilot valve therefore must move with small changes of current through the solenoid coil. By use of a magnet with a tapered air gap, force-deflection characteristics such as those shown in Figure 4A are obtained, the various curves being plotted for different numbers of ampere turns X, Y, and Z. However, since the characteristics of the biasing spring are linear (line R^1T^1), the magnet is constrained to move linearly, resulting in an operating characteristic as represented by line RST, Figure 4A. By extrapolating from the line RST, and the curves for different ampere turns, a curve such as LMN in Figure 4B is obtained. In the working range of the governor only small ampere-turn changes are necessary for satisfactory governor operation and therefore only the portion L^1MN^1 of Figure 4B, need be considered: L^1MN^1 is essentially a straight line.

Since the magnet must be responsive to small changes in solenoid current, the required pilot valve travel also must be small. In the governor under consideration the total travel of the pilot valve is 0.1 inch, whereas under normal working conditions a movement of only ±0.010 inch is required for a tie-rod velocity great enough to ensure correct parallel performance. A solenoid force of $1^1/_2$-2

pounds is sufficient to do this, while an oil pressure of 250 pounds per square inch on a piston area of approximately 1.2 square inch is ample for movement of the servomechanism.

Other characteristics of the governor are as follows:

Control coil current	0.4 ampere
Turns on control coil	1,000
Resistance of control coil	16 ohms
Diameter of pilot valve	3/8 inch

Figure 5 shows a view of the completed governor assembly. The accumulator shown mounted on top was found from test to be unnecessary and was not used thereafter.

Figure 5. Oblique rear view of an experimental electric governor

Control Circuit

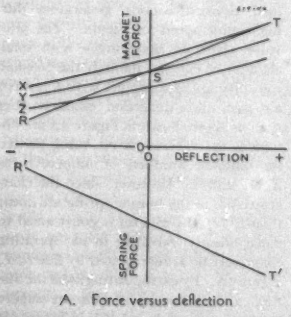
A schematic electrical diagram of the governor control circuit used for test is shown in Figure 3. The output voltage of a small 3-phase a-c tachometer with a permanent magnet field driven at a speed proportional to the output speed of the variable-ratio transmission is rectified by means of the 3-phase full-wave rectifier, S, shown. The output terminals of the rectifier are connected through a variable resistance to the governor control coil.

This control coil operates on a solenoid coupled mechanically to a three-land valve and biasing spring shown also in Figure 2. Under steady state conditions the force of the solenoid is balanced by the spring, and the valve floats in its neutral position. Any change in output speed of the variable-ratio transmission, either because of load variation or input speed changes, results in a momentary increase or decrease in current to the control coil. Balance of the pilot-valve assembly thus is lost temporarily, and oil is allowed to flow to and from the servomechanism controlling the transmission. The force on the servo pistons is such that the effective gear ratio of the drive is changed to restore original speed conditions. As soon as these are obtained, the pilot valve is returned to its neutral position. Steady state speed adjustments may be made by means of the trimming rheostat R_T. On an aircraft installation a rheostat may be mounted on the flight engineer's panel and connected in parallel with R_T to provide remote control of each generator speed. For parallel operated generators this is also an adjustment for load division, should the governor setting deviate during a flight.

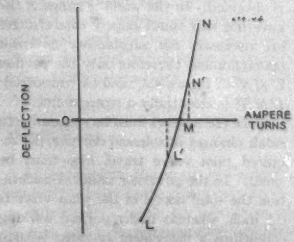
Stabilizing of the governor may be obtained by means of the circuit shown in broken lines above the control coil in Figure 3. The rheostat R_s is geared to a rack on the servo pistons, and therefore movement of the latter will result in a change in the amount of the resistance R_s in the stabilizing circuit. Since the governor control current is essentially constant, movement of R_s results in a change in voltage to the capacitor and stabilizing coil. The capacitor therefore will either charge or discharge, depending on whether the voltage decreases or increases. In either case a current will flow through the stabilizing coil, producing ampere turns in opposition to the change in ampere turns in the control coil. A stabilizing action therefore is produced.

For successful parallel operation the alternators should be controlled, so that their speed decreases with increasing load. In Figure 6A is shown the speed–load characteristics of four alternators without controls to give speed regulation. Prior to synchronizing, the speeds of the machines probably are slightly different one from the other due to inherent instrument and human error. On synchronizing, the machine with the highest initial speed will assume all subsequent load, thus giving a very undesirable condition. In Figure 6B is shown in the same order the speed-load characteristics of the same four alternators, but in this case they have controls to give speed regulation. The same initial speed errors are shown, but, on synchronizing, subsequent load is divided among the machines in proportion to their initial speed errors. The drawing is not to scale, the percentage droop being exaggerated for the purposes of illustration.

The control circuit (load-frequency droop control) giving this desired speed regulation is part of the governing system and is shown in Figure 3. One line to neutral voltage of the alternator is supplied to the primary winding of transformer T_1. The secondary winding of this transformer is midtapped and con-

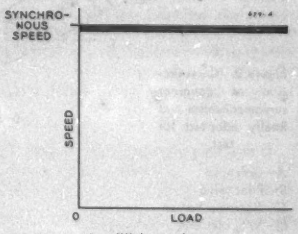


A. Force versus deflection

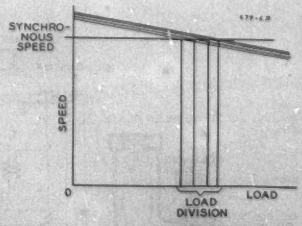


B. Deflection versus ampere turns

Figure 4. Curves of governor solenoid design characteristics



A. Without droop



B. With droop

Figure 6. Diagram showing how load-frequency droop provides for real power division

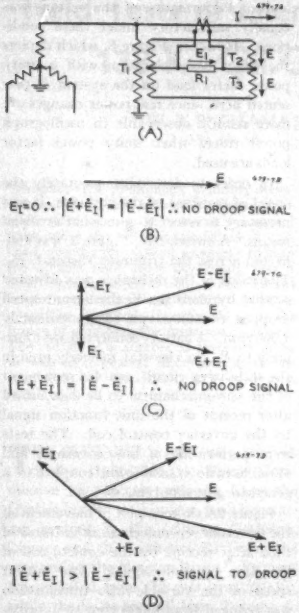


Figure 7. A. Schematic electrical diagram of a-c portion droop circuit
B, C, D. Vector relations in the primary windings of transformers T_2 and T_3 for different load and power factor conditions

B—No load
C—Zero power factor load
D—0.75 power factor load

nected through a resistance, R_1, to the primary windings of the identical transformers T_2 and T_3. The output of each of these transformers is rectified by means of selenium rectifiers S_1 and S_2. By connecting the rectifier outputs subtractive, the difference in d-c signals can be placed on the droop circuit coil connected as shown. On no load the alternator line to neutral voltage produces equal signals in the rectifiers. The resulting two d-c signals being subtractive, there is no signal to the droop circuit coil. The secondary winding of the current transformer, CT, is connected across the resistance R_1. On load, a signal proportional to alternator output current therefore is added vectorially to and subtracted from the voltage signal, thus producing unbalance in the outputs of rectifiers S_1 and S_2. This unbalance results in current flow, smoothed out by means of the capacitor-resistance network, N, shown, through the droop circuit coil. The control and droop coils are wound concentrically, the latter being connected so that on load, the flux produced is in the same direction as that of the control coil. This has the same effect as an increase in output speed of the variable-ratio transmission, and the governor acts accordingly. By means of the variable resistance, R_2, the percentage speed regulation of the alternator can be adjusted to its most effective value. On an actual aircraft installation it is expected that the value of R_2 will be fixed.

Vector relations involved in the load-frequency droop circuit are shown in Figures 7A, B, C, and D.

It is sufficient to consider the absolute magnitudes of the resultant voltages applied to the primary windings of transformers T_2 and T_3, in determining the droop coil signal voltage, since the output of each rectifier is proportional to the respective magnitude of the voltage in the transformer to which it is connected. The rectifiers are connected subtractive, and therefore the net signal to the droop coil is zero whenever the voltages applied to the primary windings of T_2 and T_3 are equal in magnitude.

In Figure 7A is shown the skeleton droop circuit and the voltages contributing to its operation. Since transformers T_2 and T_3 are identical, the voltage components, E, applied to the windings by virtue of the alternator phase to neutral voltage, are equal. Similarly a voltage component, E_1, is applied to transformers T_2 and T_3 by virtue of the drop in the resistor R_1, caused by the flow of load current through the current transformer. The voltages E and E_1 therefore will be vectorially additive in one transformer and vectorially subtractive in the other transformer.

In Figure 7B, with no load on the system, the voltage E_1 is zero, and consequently there is no signal to the droop coil.

In Figure 7C with zero power factor load the absolute value of the vector sum, $|\dot{E}+\dot{E}_1|$, is equal to the absolute value of the vector difference $|\dot{E}-\dot{E}_1|$. Again the signal to the droop coil is zero.

In Figure 7D with a load power factor of 75 per cent the absolute value of the vector sum, $|\dot{E}+\dot{E}_1|$, is greater than the absolute value of the vector difference, $|\dot{E}-\dot{E}_1|$. Consequently, a voltage proportional to the difference between the absolute values is applied to the droop coil circuit, actuating the governor in such a way as to tend to restore load balance. It is clear from the vector relations shown in Figures 7C and 7D, that the droop coil signal is sensitive to real power current and insensitive to reactive power current.

Performance Data

General

Performance data obtained at the time of writing the paper have been confined to a developmental two-generator system. Each prime mover of the system was a 450-horsepower 9-cylinder gasoline engine, coupled through a step-up gear in order to obtain input speeds to the variable-ratio transmission comparable with those expected on an aircraft installation. The gear output shaft was connected through a double universal coupling to the input flange of the variable-ratio transmission. A 3-phase a-c tachometer with a permanent magnet field was driven through a gear at half output speed and provided power for the governor control circuit.

A freewheeling device located between the variable-ratio drive and the alternator allows the alternator to be driven but does not permit it to attempt to drive the prime mover. Loading of the alternators was provided by water-cooled calrod units and air-core reactors, the continuous rating of the alternator being 30 kw, 40 kva, at 400 cycles per second and 208Y–120 volts.

The presence of the freewheeling unit between the drive and alternator made synchronizing of the alternators a simple matter. Successful parallel operation

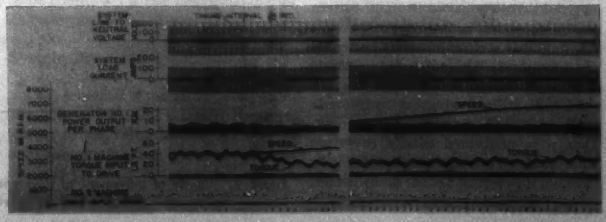


Figure 8. Oscillogram showing transient division of real power between generators by governor action during acceleration of one engine

was achieved, the generators staying in step during various types of disturbances and dividing load equally under steady state conditions and reasonably well during transient disturbances (see Figure 8). The general performance of the governors was very satisfactory throughout a series of system tests which followed successful parallel operation.

Stabilizing Circuit

A considerable amount of previous development work on governors for gasoline engines used in tanks greatly expedited the development of the governor to control the variable-ratio transmission. Because of the rates of response and the values of inertia involved in controlling the tank engines, stabilizing circuits were required in governors built for this purpose. A variable resistance, R_s, and capacitance, C_s, connected, as shown dotted in Figure 3, to a second solenoid coil enabled this stabilizing to be achieved. In the case of the governor for use on aircraft where a variable-ratio transmission is to be controlled, the slip is relatively small and the speed of response high. Consequently the afore-mentioned type of stabilizing is unnecessary. Tests showed, however, that if an application should occur where stabilizing is required, this could be accomplished readily.

Droop Circuit

The value of the resistance R_3 in the droop circuit (Figure 3) was set arbitrarily to give a 5 per cent frequency decrease linearly from no load to full load on the alternator. Load division under steady state conditions was excellent, each generator taking an equal share of the load. By varying the value of R_2 the percentage droop was decreased. For values less than 4 per cent the load division became less satisfactory and erratic. The value of R_3 therefore was fixed to give a linear frequency droop of 5 per cent with full load on the alternator. With no load frequency of 420 cycles per second, a full load frequency of 400 cycles per second thus was obtained.

Part of the load on a military airplane using the a-c system for electric power may be thyratron controlled gun turrets. When in operation, these control circuits will produce a d-c component of current in the a-c system. This will tend to saturate any current transformers which may be used there. Since a current transformer was an essential part of the droop circuit, tests were performed with a thyratron controlled gun turret load to determine its effect on the operation of the droop circuit. It was found that load division was satisfactory, the saturation of the current transformers used having no noticeable effect on governor action.

Speed of Response

The general speed of response of the governor is illustrated in Figure 8 which shows two sections of an oscillogram taken with the machines operating in parallel and one engine being accelerated. The portion between the two sections of the oscillogram represents a time interval of 0.9 second. The average rate of acceleration at the input shaft to the drive for the total interval is approximately 2,000 rpm per second, the machines staying in step throughout. The left-hand section of Figure 8 shows conditions prior to accelerating. The system is carrying approximately 30 kw of load. The machine being accelerated assumes more load while the other machine takes less load as indicated in the oscillogram. However, before the acceleration is completed the governors have begun to restore conditions, so that the machine not being accelerated begins to assume its share of the load again. This is illustrated in the right-hand section of Figure 8. Other oscillograms were taken showing the effects of acceleration and deceleration when the system was supplying lagging power factor loads. Performance of the system was equally satisfactory under these conditions. However, Figure 8, which depicts the effect of acceleration with a unity power factor load on the system, is presented here, since real power changes are more readily observable in oscillograph power traces when unity power factor loads are used.

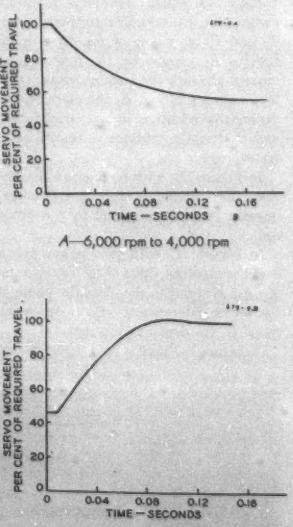


Figure 9. Curves of movement of governor servomechanism after change in electric signal

In order to determine accurately the speed of response of the governor, it was necessary to resort to somewhat artificial means. A switch *SW*, Figure 3, was connected across the trimming rheostat, R_T. The value of the resistance was adjusted so that by closing *SW*, the output speed dropped from 6,000 rpm to approximately 4,000 rpm. A battery connected appropriately to R_s, the rheostat formerly used in the stabilizing circuit, enabled movement of the servomechanism to be determined after receipt of the unit function signal by the governor control coil. The tests were performed on one governor, and variable-ratio transmission coupled to a generator but supplying no load.

Figure 9A shows a plot of movement of the governor servomechanism in terms of time after receipt by the control coil of the unit function signal. The output speed of the variable-ratio transmission was reduced from 6,000 rpm to approximately 4,000 rpm. With an input speed of 3,000 rpm this gave a change in drive ratio from 2:1 to 1.3:1.

Figure 9B shows a similar curve obtained by opening the switch *S* (Figure 3) and thus increasing the output speed from 4,000 rpm to 6,000 rpm. Here there is an overshoot of approximately 2 per cent. This is due to the inherent delay of the moving parts and the oil pressure of the hydraulic system, reaching steady state conditions after completion of the unit function change in electric signal.

The successful operation of the governor over a period of 200 hours under severe conditions brought about by many stops and starts with heavy loads often applied and removed suddenly indicates that a suitable automatic control has been developed for the variable-ratio transmission so necessary in the parallel operation of main engine driven aircraft alternators.

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Field Tests of Interrupting Capacity of 138-Kv Oil Circuit Breakers

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Synopsis: The preliminary planning necessary to estimate the amount of current to be interrupted on a large network for staged tests under short-circuit conditions is outlined, also the precautions necessary to keep the applied fault from developing into a total system interruption. The circuit breakers under test are identified, various quantities required for record, and the means of obtaining the same are discussed. The results of a number of tests are given as well as a general discussion as to the conditions of the tests and of results obtained.

THE 25-CYCLE high-voltage network of the Hydro-Electric Power Commission of Ontario extends from the Quebec border to Windsor, with generating sources on the Ottawa, Gatineau, Lievre, and St. Lawrence Rivers in the east and on the Niagara River.[1] Primary transmission from the east is at 230 kv, while the loads located from Toronto to Windsor are supplied from a 115-kv network covering the afore-mentioned area.

The total generating capacity normally interconnected and supplying this network is in the order of 1,750,000 kva. The short circuit kilovolt-amperes on the 115-kv network has increased with system growth, with the result that, although circuit breakers had been provided at many points with the highest interrupting capacity available from time to time, the increase in short-circuit kilovolt-amperes always had to be considered in regrouping lines or paralleling busses. In some cases it has been necessary to sectionalize busses to reduce short-circuit currents, where best operating practice indicated parallel operation. The necessity of operating all generating sources to their capacity during the war also has tended to increase the short-circuit kilovolt-amperes.

When considering the point to which it would be reasonably safe to interconnect the network without inviting failure of the circuit breakers to interrupt faults, the Commission's engineers were required to answer the question, what modifying factor, if any, should be applied to the interrupting capacity of the circuit breaker at 60 cycles, as demonstrated by laboratory and field tests, when this circuit breaker was required to interrupt 25-cycle current. There appeared to be no clear-cut answer to this question. After discussion with manufacturer's engineers, it was decided to make the tests described in this paper on a modern oil circuit breaker, by having this circuit breaker interrupt actual system fault currents up to its rated interrupting capacity and observing the results.

A 138-kv single tank circuit breaker equipped with type BH deion grid, located at Burlington transformer station, having rated interrupting current of 7,950 amperes at 110 kv, was selected, the manufacturer being asked to place this circuit breaker in "factory condition" prior to the test. It also was decided to make a test on a second circuit breaker of the same interrupting capacity by installing in it temporarily an improved interrupting device, known as the type MF grid. This assembly was to be tested at not over 13,200 amperes at 110 kv.

Preliminary Work

Certain preliminary studies are required before tests of this nature can be made. Important studies include:

1. Determination of system required, including departures from normal network and generating capacity.

2. Careful scrutiny of the system and its relay protection, to determine the possibility of loss of tie lines, busses not involved in the fault, frequency changer ties, synchronous loads, and generating capacity and, where it could be done, to prevent their occurrence.

3. Listing of quantities to be measured and providing of equipment for measuring these quantities.

The circuit breaker to be tested also must be conditioned, if the tests on it are to be considered a fair demonstration of its performance.

System Required

The American Standards Association "Standard for Oil Circuit Breakers, C37-4" defines rated interrupting current as the *total* rms current at the time the contacts part. It was agreed that these standards were to apply. One problem in the preliminary work became that of determining the system setup required to produce a short-circuit current, as defined by the ASA Standard, as nearly equal to, but no greater than, the rated interrupting current given by the manufacturer.

The system upon which the fault was to be placed is shown in Figure 1. Burlington transformer substation is located at the heart of the 115-kv network. Although the only sources of short-circuit current close to the point of fault are the two 40,000-kva synchronous condensers at Burlington, there are points of infeed from eastern sources over the 230-kv network and from Niagara River plants over 115-kv lines. Generators in the latter plants, which are on busses separate from the 115-kv subsystem on which the fault was placed, also supply current to the fault by back-feeding through 230-kv transformers at Burlington to the common 230-kv bus.

It had been decided that two preliminary tests would be made, one at approximately 1/4 and one at 1/2 rated interrupting current before the final test on the lower rated circuit breaker, and one preliminary test at not over 7,900 amperes on the higher rated contact assembly. To determine the initial values of symmetrical current, and the system rearrangement required to produce them, the system shown in Figure 1 was placed on the network calculator.

System generation and loads for a normal Saturday were used with the impedance of generating sources represented by their subtransient reactance.

After a number of trials on the calculator one grouping of lines was found such that with the fault located at the distant end of the line whose line circuit breaker would be under test, approximately 1/4 rated current would flow initially, and the same network with fault located at the near end of the same line would produce approximately 1/2 rated current. It should be noted that rather severe restrictions were placed on modifying the system to develop the required values of short-circuit current. Sufficient generation had to be retained to supply the system load, and circuits could not be opened to the point where service security would be threatened seriously.

The system required to give a 3-phase

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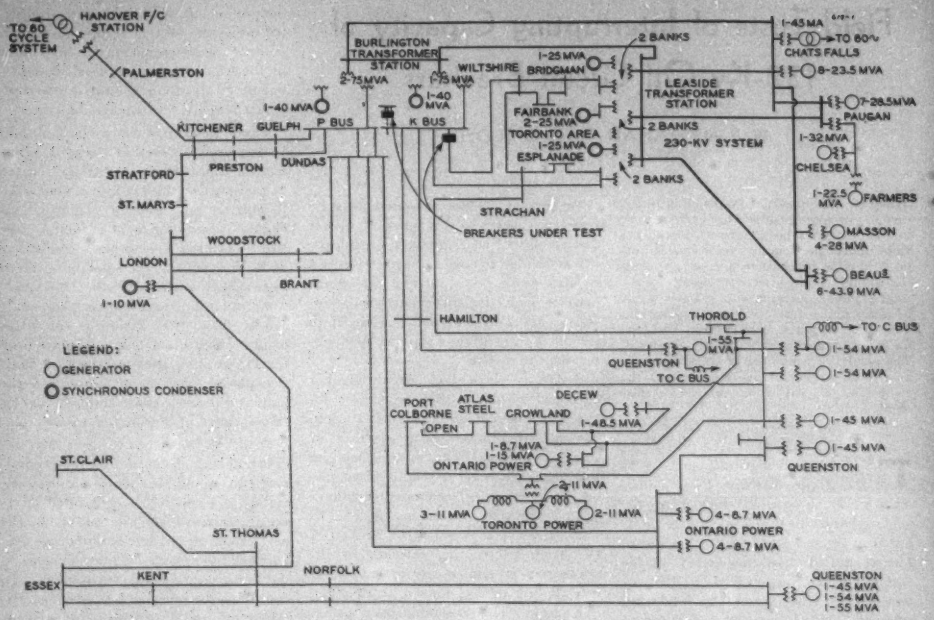

Figure 1. Niagara division transmission network of the Hydro-Electric Power Commission of Ontario

short circuit of 7,900 amperes and that required to produce approximately 13,000 amperes likewise were determined. For the latter the two 115-kv busses at Burlington would be parallelled and both synchronous condensers operating. These condensers could be used to advantage to obtain vernier calibration of the current, as the amount of infeed from each was known from the calculator readings.

Calculator readings give only *the initial symmetrical* current, so that the relation between this current and the *total* current at the time the contacts separated remained to be determined.

The d-c component of total current decreases exponentially according to the formula $i = I_o e^{-Rt/L}$. The ratio R/L is the ratio of resistance to inductance of the system looking into the system from point of fault. This ratio was determined from measurements on the calculator and found to be 33, giving a time constant of 0.03 second for the d-c component. It, therefore, was concluded that at 3 to 4 cycles (0.12 second to 0.16 second) after beginning of the fault, the d-c component would have disappeared, or at least it would be so small as to have negligible effect on the value of total current.

Standard decrement curves[3] indicated that, when corrected for frequency, the a-c component of total current at 3 to 4 cycles was practically the same as the initial a-c component.

As a result of the foregoing conclusions, the decision was made to use the system setup determined on the calculator, including as nearly as possible the same system generation without modification.

Provision for Service Security

It was of utmost importance that impairment to service should be avoided. The expected behavior of the system and its associated relay protections under severe 3-phase faults were studied to determine points of weakness. As a result of this study it was decided all frequency changer ties would be opened and certain relays on tie lines blocked for the brief test period. Backup protection for the circuit breakers under test was provided, and tested, and arrangements were made to place observers at widely separated key points to block those relays considered necessary and to be available if unforeseen trouble developed. Some loss of synchronous load appeared to be unavoidable and was accepted.

Study of Quantities to Be Measured

The quantities having direct bearing on the behavior of the circuit breaker itself and methods developed and used to obtain them are described later in the paper. Advantage was taken of every opportunity afforded by tests of this nature to obtain information on system and relay behavior. As a result observations quite foreign to those required for the test itself were included in the program, and useful data were obtained. To avoid confusion these data are not included in this paper.

Description of Circuit Breakers and Contacts

The two circuit breakers tested are 138-kv type BQOB oil circuit breakers manufactured by the Canadian Westinghouse Company. The 3 poles are mounted in a single floor-mounted tank. The spacing at the top of the bushings is the same as the minimum spacing for bushings of 3-phase transformers of the same voltage class.

The bushings are standard oil-filled condenser type, with deion grid contacts,

Figure 2. Type BOOB 138-kv oil circuit breakers at Burlington transformer station

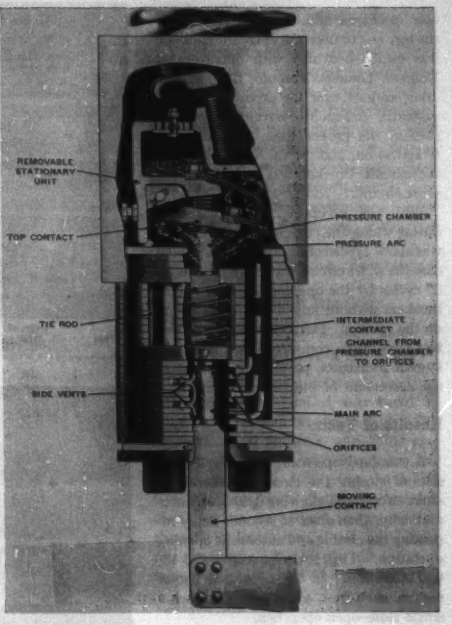

Figure 3 (right). Section through 138-kv type MF contact multiflow 5-cycle Delon grid, 2½ million kva

type BH for the 8-cycle 1,500,000-kva rating, and type MF for the 5-cycle circuit breaker rated at 2,500,000 kva. Each grid is surrounded by a heavy circular insulating tube, which acts as a barrier between phases. Entry to the tank is through a manhole at the side of the tank. Ample space is available between the contacts and the tank for inspection and maintenance.

Figure 2 shows a row of these circuit breakers at Burlington transformer station. Figure 3 shows a section through the type MF contact.

Measuring Equipment

Past experience indicated that high internal pressures could be developed and oil ejected when circuit breakers opened on heavy fault currents. A pressure gauge therefore was installed giving an output suitable for oscillographic records. This gauge consisted of a Crosby steam gauge, in which a slide wire potentiometer had been substituted for the oscillating cylinder and fitted with a 60-pound spring. The gauge was connected to a 1-inch bushing, the latter welded to the tank about 27 inches above the concrete base. The pressures that might occur were quite conjectural, but the choice proved satisfactory for these tests.

Circuit breaker tanks also had been known to shift on their bases, and a detailed study of motions and stresses was suggested. Zenith vibration recorders were mounted, one on each of the four lifting lugs at the top of the tank. These units contain circular clock-driven charts and are very sensitive to vertical displacements that occur at high accelerations.

Other stress indicating devices, such as scratch extensometers and electric units of the strain-resistance type, were attached at the base of the tank and to the holding-down bolts.

A special travel indicator was designed, attached to the indicator arm, and a calibration curve of the relative motion between the vertical lift rod and the indicator arm was obtained. To obtain a continuous accurate record, two slide wires with independent sliding contacts were used in parallel as a potentiometer.

Line to ground voltages were obtained from the secondary windings of three potential transformers, the primary windings of which were connected line to ground on the 115-kv bus.

Currents were measured by inserting Weston multiratio current transformers in the secondary windings of the regular bushing-type current transformers, to provide a further stepdown of current to the oscillograph shunts. An over-all calibration of the oscillograph element circuits was made by circulating alternating current in the primary winding of the Weston current transformers.

The entire group of measurements required the use of 18 and occasionally 20, oscillograph elements plus some mechanical records.

Procedure on Test

Immediately before each test, duly accredited representatives of the manufacturer and of the engineering and operating departments of the Commission were consulted as to final readiness and consent obtained to proceed with the test.

Arrangements previously had been made covering the system required for each test. A request was made through the load supervisor to have this system arrangement established, and at the same time the relay section of the operating department was conferred with for any special checking or blocking of relays to maintain protection without interfering in any way with the test proposed.

Finally, the instrument operators were checked for readiness. The last group of items checked consisted of oscillographs and mechanical recorders, which were automatic in operation.

A public address system is installed in various buildings and in the yard in Burlington transformer station. The oper-

ator in charge announced to all present the test was to take place; communication was established also with operators at Niagara, Dundas, Toronto, London, and other stations, over the private telephone system. A 2-minute warning was given, then at the proper time, 10 seconds, 9, 8, and so on, and on the stroke of zero the circuit breaker was closed on the short circuit.

With one exception the actual time during which the current was maintained was about 1/8 second. In the exceptional case the short circuit was cleared in about 30 cycles by the opening of seven circuit breakers without any major interruption on the system. Data obtained from this test gave more complete information on system transients, permitting analysis of the decrement of short-circuit current.

Results of Tests

A standard operating duty cycle consists of closing the circuit breaker on a short circuit and allowing it to open automatically, then after 15 seconds delay repeating the closing and automatic opening operation. This is designated a CO-15-CO operation. In the tabulated list of results each test as listed indicates a single close-open operation.

Figures 4 and 5 are typical records of

1. The red-phase line-to-ground voltage.
2. The three 115-kv line currents.
3. The trip-coil current.
4. The record of the travel indicator.

The data shown on Table I were obtained from the oscillograms. The current listed for each test is the maximum measured on any one of the 3 phases. Duplicate records taken on another oscillograph provided a satisfactory check on the current values as listed.

The current, arcing time, and total duration of fault current were obtained by the method outlined in the American Standard for "Alternating-Current Power Circuit Breakers 37.4 to 37.9," inclusive.

The results of the electrical tests require very little comment. Close inspection of the oscillograms indicate, in some cases, an erratic variation in resistance of the arc while it was being quenched.

Vertical motion to a maximum of 0.4 inch was recorded by the Zenith recorders at the top of the tank. The precision of the figures does not warrant drawing any elaborate conclusions, but some points are of more than passing interest. Table II shows the record obtained from these instruments.

The mechanical shocks registered on the first three tests seem to be independent of current, as greater motion (approximately twice as much) was recorded on test 2, with current at 4,720 amperes as occurred on test 3-2, when 7,720 amperes were interrupted.

Table I. Tests on 138-Kv Circuit Breakers on 3-Phase Short Circuit

Test	Maximum Current at Parting of Contacts, Amps, Rms	Phase	Type of Grid	Arcing Time, Cycles	Duration of Fault Current, Cycles	Voltage Recovery, Per Cent	Capacity Interrupted, Millions of Kva
1-1	2,730	Blue	BH	1.4	3.4	93.5	0.54
1-2	2,730	Blue	BH	1.7	4.0	92.5	0.54
2	4,720	White	BH	1.7	3.5	85.5	0.91
3-1	7,490	Blue	BH	1.4	3.5	91.0	1.46
3-2	7,720	Blue	BH	1.6	3.4	92.5	1.48
4A	7,250	White	MF	1.0	3.0	91.5	1.37
5-1	13,100	Red	MF	1.2	2.9	88.0	2.58
5-2	13,000	White	MF	1.2	3.0	83.5	2.57

Table II. Record of Zenith Recorders at Top of the Circuit Breaker in Inches

Test	Type of Grid	Recorder 1	Recorder 2	Recorder 3	Recorder 4
1	BH	Up 0.06	0	0	Up 0.16
2	BH	Up 0.33	Up 0.4	Up 0.3	Up 0.2
		Down 0.33	Down 0.4	Down 0.33	
3-1	BH	Up 0.16	Up 0.2	Up 0.33	Up 0.1
3-2	BH	Up 0.13	Up 0.2	0	Up 0.13
		Down 0.13			Down 0.13
4A	MF	0	0	0	0
5	MF	0.2	Up 0.06	Up 0.1	Down 0.06

This suggests that the acceleration and deceleration of parts played an important part in the over-all motion of the tank. It may be noted that the vertical motion of the top of the tank of the circuit breaker equipped with the MF grids was substantially less than on that with the BH grids, though the current interrupted was very much greater.

No quantitative results have been obtained from the records of stresses at the base of the tank because of various difficulties in anticipating their performance. It is conclusive, however, that, if stresses of objectionable magnitude had occurred, they would have been detected on the records.

The hydrostatic pressures set up in the tank appeared in the form of waves of decreasing amplitude. The maximum positive pressure was greater on the circuit breaker equipped with BH grids but did not exceed approximately 25 pounds per square inch as recorded. Even this was not a sustained pressure but a pressure-wave reflected back and forth with decreasing amplitude. By dividing the time interval between pulses, the actual time of the event in the circuit breaker contacts which causes the pulse may be estimated and identified.

The pressure gauge records from tests 2, 3, and 5 have been transferred to a single chart (Figure 6) for better comparison. A timing wave for test 2 was not available on the same film, but the action is sufficiently like test 3 for identification.

The small impulse registered first in each case seems to occur at the closing of the contacts; the heavier pressure waves continued for three surge-cycles after the arc was extinguished.

This device would not record negative pressures, so it is not possible to continue the analysis of the pressure waves further, though it is an interesting and unexpected aspect of the problem.

Samples of the insulating oil were taken after each test on the circuit breakers, and later tested for dielectric strength. No deterioration could be detected from the breakdown values, though the oil had become somewhat darker in color.

Comparison of Test Results With Calculator Values of Current

A comparison of values of current obtained on test with network calculator values has been made, to establish the accuracy of the latter in determining circuit breaker interrupting capacity.

The preliminary tests at 1/4 and 1/2 rated current were found to be about 15 per cent higher than given by the calculator, but this was due in part at least to increased and different distribution of generation from that used on the calculator. There was also a slightly different system arrangement. These variations were unavoidable but indicate that the system must be set up as accurately as possible, if close estimates of fault currents are required.

Figure 4. Oscillograph record of current interruption with BH grid

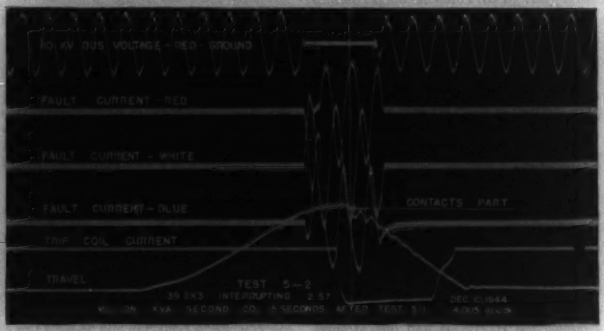

Figure 5. Oscillograph record of current interruption with MF grid

There was 5 per cent variation in fault current as measured on two field tests made with identical system arrangement, including the same generation.

On all tests it was found that the d-c component, although still measurable, added only one or two per cent to the total current. The largest value of this component on any test as measured, was approximately 15 per cent of the total.

On all but one test the duration of fault current was so short that no accurate estimate of decrement could be made. The agreement between calculated and test values of current, the former being initial values of rms symmetrical current, was an indication that for the time periods of interruption obtained on these tests it is safe to assume that no decrease in current occurred. Any error due to this assumption is in favor of the circuit breaker from the point of view of circuit breaker application, as it gives higher currents than the actual currents interrupted.

On one test the current through the circuit breaker existed for 30 cycles, until the fault was cleared by backup relays and system voltage restored to normal. This test, although it was a failure as a test on the circuit breaker, gave very useful data on the behavior of this system under 3-phase short circuit.

The currents recorded have been analyzed with the following results: The d-c component had an average short-circuit time constant of 0.06 second, compared with the 0.03 second obtained from calculator readings.

A comparison of test current (average of three phases) as measured and total current obtained from standard decrement curves, the latter corrected for a 25-cycle system by assuming an average open circuit time constant for this system of 10 seconds indicated close agreement (Figure 7). The decrement curves give values of total current, assuming a totally displaced wave. As no one of the test currents was totally displaced, it was possible to compare only the a-c components.

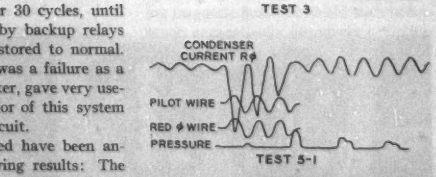

Figure 6. Record of pressures developed in circuit breaker tank on selected tests

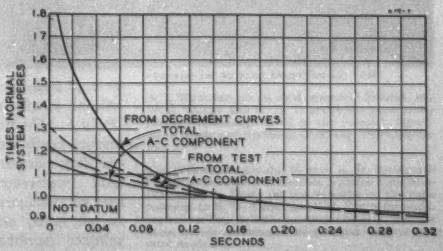

Figure 7. Comparison of test current with that from standard decrement curves

Condition of Circuit Breakers Following Tests

Circuit Breaker Having BH Grids

The circuit breaker in which the type BH grids were installed was rated at 7,950 amperes and was tested at 2,700 amperes, 4,700 amperes, and 7,700 amperes approximately with inspection following each test. Following the initial test there was only slight discoloration of oil. After the second test inspection showed discoloration of oil and slight pitting on the edge of the moving contacts. After the third test there was con-

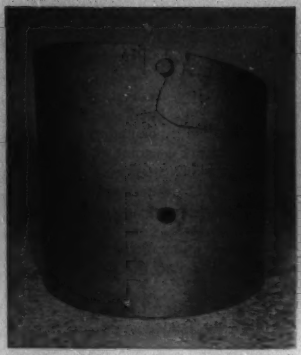

Figure 8. Micarta shield from type BH grid assembly after test at 7,900 amperes, showing crack at bolt hole

Figure 10. Type MF contact assembly and contacts after test at 13,100 amperes

Figure 11. Moving contact assembly type MF after test at 13,100 amperes

siderable discoloration of oil but no decrease in its dielectric strength. The moving contacts were burned slightly on the outside edges. The Micarta shield on one bushing was cracked at a bolt hole (Figure 8). The alignment of lift rods, moving contacts, and grids had not changed.

The Deion grids were removed and disassembled. No permanent damage was discovered, the only evidence of the interruption being a black substance blown through a number of the stacks (Figure 9).

Circuit Breaker Equipped With Type MF Grid

This circuit breaker interrupted 13,100 amperes with very little movement of the tank. The condition of the contact mechanism is shown on Figures 10 and 11. In our opinion the contact mechanism could have interrupted an undetermined further number of short circuits at 2,500,000 kva without overhaul becoming necessary. It therefore fulfills the requirements of the American Standard C37.4 in this regard.

Conclusions

1. It is quite feasible to test circuit breakers by staged tests on a large system, provided suitable precautions are taken, and the necessary preliminary work is done to establish the generation and line arrangement required to produce the specified value of short circuit current. On a large system use of the d-c or a-c calculator to determine the system required is essential.

2. Three-phase short-circuit current values at 25 cycles obtained on the calculator agree with actual system values, at least to the same accuracy as obtained on successive tests (5 per cent), using subtransient values of generator reactance and no decrement, if the circuit breaker time is 3 cycles.

3. The standard decrement curves modified for 25-cycle conditions, agree with actual system behavior within the accuracy of the test itself.

4. The circuit breaker with rated interrupting capacity of 1,500,000 kva is capable of interrupting 7,950 amperes at 110 kv and 25 cycles, within the meaning of the American Standard C37.4.

5. The contact assembly or type MF grid is capable of interrupting 13,100 amperes at 110 kv and 25 cycles, within the meaning of the American Standard C37.4.

6. Comparison of results from this test with those made previously in the high current test laboratory at 60 cycles indicates that the margin between rated and maximum interrupting capacity appears to be reduced for 25-cycle faults.

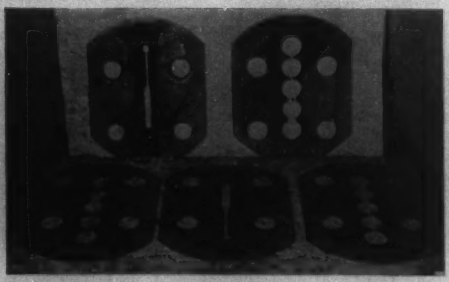

Figure 9. Plates from type BH grid stack after test at 7,500 amperes, showing material blown between plates by the arc

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Electronically Balanced Recorder for Flight Testing and Spectroscopy

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Synopsis: A multiple-point potentiometer recorder for thermocouples is described having a slidewire driven to balance by a small induction motor powered from a 6L6 electron tube. The preamplifier gain is sufficient that the conventional input transformer (voltage step-up type) is not required, and thus a high impedance input circuit is made available. This permits the use of small capacitance values in the *RC* circuits for signal filtering and motor damping. The relation of this to the short balancing time (1.5 seconds) is discussed.

Spectroscopy supplied the incentive for the development of two additional but similar recorders. The first of these is a curve-drawing multiple-range microampere recorder with the smallest range 0.5 microampere, and with a balancing time of less than 1.0 second. The second is a multiple-range current-ratio recorder requiring only about 10 microamperes for the reference current.

IN A PREVIOUS PAPER[1] there was described the application of this recorder in potentiometer form to the measurement of 140 thermocouple temperatures during flight tests of planes. The switching of the thermocouples was described and the need for the short balancing time in the recorder was explained, but a description of the recorder itself was beyond the particular purpose of that paper. Interest in the recorder for other uses, such as wind tunnel testing, turbine checking at sea, and, in modified forms for spectroscopy is the reason for the present paper on the recorder itself.

Potentiometer Recorder

Figure 1 of the multiple-point potentiometer recorder shows the scales, the pointer, a section of the 21-point print wheel (under the pointer), and the perforated strip chart. The print wheel is pressed onto the paper once every 1.63 seconds by mechanical linkage from the same synchronous motor that drives the chart at constant speed. There is a violin string and pulley connection between the print wheel carriage and the slidewire potentiometer. All this is conventional.

Figure 2 shows the basic potentiometer circuit which is used. In operation, if the thermocouple gets hotter, its electromotive force increases above that of the potentiometer. The detector notes the unbalanced voltage and, through the balancing system *A–A*, moves the contact to balance and with it the print wheel and pointer. The current through the potentiometer is standardized by manually moving the battery rheostat, with the switch in the standardizing position, until the potentiometer contact comes within a limited region, as indicated by the pointer coming within a marked region of the scale.

Reference Junction Compensation

The circuit of Figure 3 is used for reference junction compensation. It is unconventional, as the reference junctions are remote from the recorder with plug connectors *X* of uncertain contact resistance in the leads 1, 2, 3, and 4. To minimize the effects of contact resistance and still have the reference junctions remote from the recorder, a complete bridge containing the compensating coils is located at the switch box with large end coil resistors R_A and R_B so the bridge can be supplied from the full 1.2 volts. 1.2 volts is the "end point" voltage for the dry battery with this circuit.

Mechanical Construction

In Figure 4 the door and the chart table are hinged away showing the slidewire, in large pan shaped enclosure, its vertical shaft and its direct gearing to the balancing motor. In the rear of the case, between the motor and slidewire shaft, can be seen one of the tubes in the amplifier, the chassis of which is hidden.

The amplifier and motor make up the balancing system shown as the detector and dotted line *A–A* of Figures 2 and 3.

Amplifier

The amplifier handles the unbalance as a 60 cycles per second a-c signal obtained by conversion from the d-c unbalance. The conversion is accomplished by a vibrator driven synchronously at line frequency as shown in Figure 5A. A blocking capacitor *C* prevents direct current from flowing from the thermocouple circuit to the tube or conversely. Four stages of triode voltage amplifiers are used together with one beam power output stage (6L6) with transformer coupling to one phase of the motor. The other phase of the motor is connected directly to the line. The quadrature phase relation required between the two motor windings is met by a fixed amount of phase shift in the vibrator drive-coil circuit. The mechanical drive from the motor to the slidewire completes the feedback loop. By using direct current on the heaters of the triodes, and by using rubber shock mounting on the low-level tube (first two stages), the total noise is held to less than seven microvolts referred to the first grid.

Filter Circuits

External circuits may produce alternating voltages in the thermocouple circuit as a result of capacitive or inductive coupling. If these voltages reach the detector input circuit, some interfering voltage will appear at the first grid. The vibrator suppresses the fundamental component but, like all modulators, adds components at new frequencies. The 60 cycles per second component is the only one which produces torque in the motor, but the other frequencies are almost as bad because they overload the amplifier. When overloaded at an odd frequency, the amplifier cannot handle the regular 60 cycles per second signal as it should.

All this points to the need for filtering out alternating voltages "picked up" by the thermocouple or its leads. Figure 5A shows the four-section resistance capacitance (*RC*) filter that is used. Inductances were not used for the series elements because of their inherent characteristic of "picking up" voltage from stray fluctuating magnetic flux. To shield such inductances magnetically introduces complications, size, and expense. The *RC* filter never can be built to have the sharp frequency cutoff of the *LC* filter, but it was found that it could be built sufficiently sharp to meet the requirements. The requirements are:

1. Attenuation of 60 cycles per second (and higher frequencies) by a factor of 500 or more (loss of 54 decibels or more).

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The authors are grateful to Mrs. A. H. Springman for calculations on the reference junction compensation, to P. A. Towle for the slidewire on the ratio recorder, to E. W. Yetter and V. J. Porter for building and testing the ratio recorder, and to I. Melville Stein for his encouragement at times when it was most needed.

Figure 1. Multiple-point potentiometer recorder

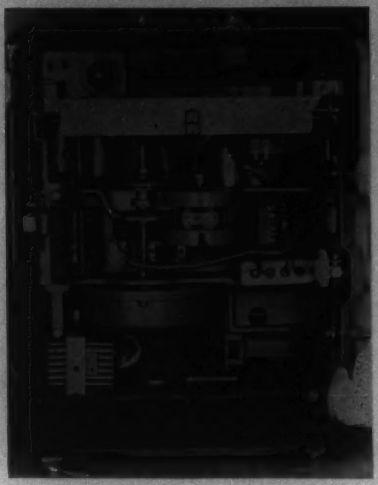


Figure 4. Internal view of recorder

2. Transmission of low frequencies of about one cycle per second and lower to 0.998 or better (loss of 0.016 decibel or less).

Requirement 2 could be stated as follows: After switching from a cold couple (reading at low end) to a hot couple (reading at the high end) the voltage at C_4 shall assume the voltage of the hot couple to within 0.2 per cent in 1.5 seconds or less.

Theoretically, the use of multiple sections in the filter is adequate to meet these conflicting requirements. Experimentally it was found that this was not sufficient. If electrolytic capacitors were used, requirement 2 would not be met. Many samples of electrolytic capacitors of many types and ratings have been tried. A typical result is shown on Figure 6A, which is a recorder response curve made with the chart driven at high speed. A satisfactory result with paper capacitors of the same 60 cycles per second capacitance is shown on curve B of the same figure. The reason for the excessive delaying action of the electrolytic capacitors was not investigated further. It may be the result of interfacial polarization inherent in the complex electrolytic film.

The impedance looking into this filter from the detector side at low frequencies (and direct current) is 20,000 ohms. The impedance of the detector is greater than this so it receives the greater part of any change in thermocouple voltage. Therefore the combination of high impedance detector and multisection RC filter using paper capacitors insures that the detector will receive changes in the thermocouple voltage without serious delay or attenuation.

Damping

Because of the inertia of the balancing motor, there is a tendency for it to overshoot the balance point. This is avoided by reversing the torque shortly before the balance point is reached. The torque is reversed by reversing the input to the detector, and this is done by introducing a voltage proportional to the motor velocity.[3] As the slidewire and motor are geared together, the slidewire velocity is proportional to the motor velocity. Figure 5B shows a simple circuit for which the output voltage E_2 is proportional to the rate of change of the input voltage, dE_1/dt, provided only that dE_1/dt has been constant long enough for the transient to have expired. If the circuit of Figure 5B were inserted into Figure 5A at B–B, there would be delivered to the detector mesh a voltage proportional to velocity as required. Of course, no voltage proportional to slidewire position would be delivered; however, if the circuit of Figure 5C is used, the voltage E_2 delivered to the detector mesh is exactly one-half the voltage E_1 of the slidewire when the slidewire comes to rest, and the transient has expired. When the slidewire is moving there is a component in E_2 proportional to the velocity. The time constant of the transient is the parallel resistance from

Figure 3. Circuit used for reference junction compensation

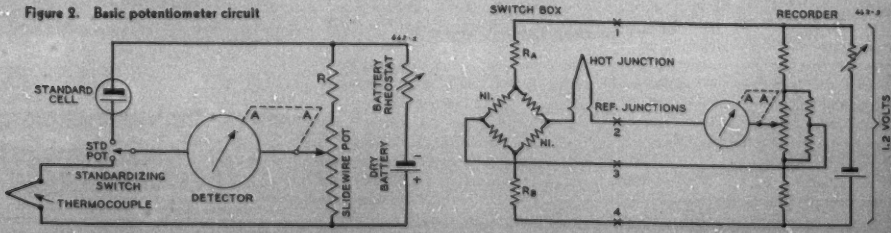


Figure 2. Basic potentiometer circuit

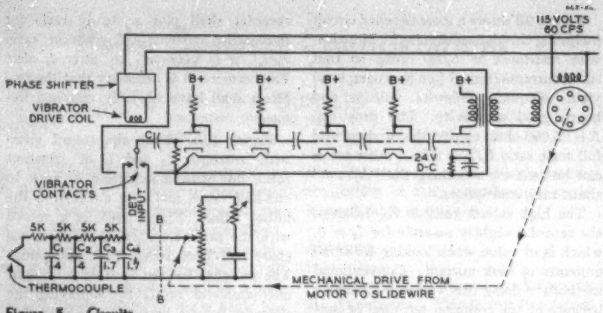
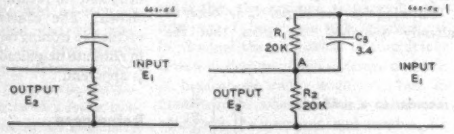


Figure 5. Circuits for balancing, filtering, and damping

A—Circuit without damping network
B—Explanatory network
C—Damping network



Resistor values are given in ohms and capacitor values in microfarads

point A times capacitance $= \frac{R_1 R_2}{R_1 + R_2} C_4 = 10{,}000 \times 3.4 \times 10^{-6} = 0.034$ second. This is so small as to have only a secondary effect, and the main object is accomplished, that is, to introduce a voltage proportional to velocity for the purpose of damping. The damping is sufficiently good to permit switching, completing a full scale balance and printing in 1.63 seconds.

It will be noticed that with this circuit some current is drawn from the slidewire even at balance. Quantitatively, however, it would require 40 ohms resistance in the slidewire, and its contact, to introduce an error of 0.1 per cent, and no such resistances ever have been found.

With the filter circuits and damping circuits described in the foregoing, and with the high impedance detector, two things are accomplished:

1. Large unbalances are completed in a minimum time without overshoot.
2. The voltage level at the detector is kept as high as possible, and therefore has the greatest possible margin above stray thermal electromotive forces.

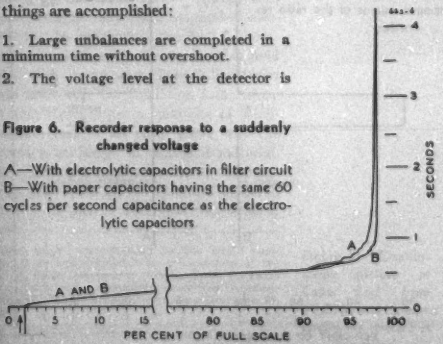


Figure 6. Recorder response to a suddenly changed voltage

A—With electrolytic capacitors in filter circuit
B—With paper capacitors having the same 60 cycles per second capacitance as the electrolytic capacitors

Microampere Recorder

For the recording of thermocouple temperatures, a potentiometer recorder is required because it is the open circuit (zero current) voltage that is the function of the temperature. For the recording of light or other radiation on a barrier layer* photoelectric cell, a current recorder is required because it is the short circuit (zero voltage) current that is the function of the radiation.

Figure 7A shows, in simplified form, how the slidewire type of null recorder can be arranged to present zero voltage to the photoelectric cell at balance. When any appreciable voltage does appear across the photoelectric cell, and hence across the detector, it operates through A–A to move the slidewire and so changes the current through the calibrated resistor until that current equals the current from the photoelectric cell, thus returning to zero the current through the detector and the voltage across the detector and photoelectric cell.

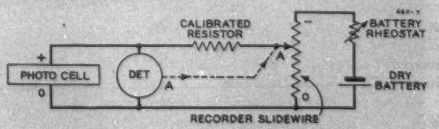
Figure 7B shows how filtering and damping are added. It will be noted that resistance is inserted between the photoelectric cell and detector for the purpose of filtering yet this resistance does not prevent the photoelectric cell and the detector reaching zero voltage at balance, as no direct current flows through this resistance at balance. As the slidewire has a low impedance, all three capacitors contribute to the filtering of alternating current from the photoelectric cell circuit away from the detector.

The damping is provided by capacitor C_3 which gives a component of voltage across the detector proportional to slidewire velocity. Figure 8 shows balancing curves with the chart speeded up in order to show detail. The balance time is approximately 0.8 second extrapolated for a full scale change. Most of the time the motor is running at top speed which is near to synchronous speed. The time lost in getting up to speed is 0.06 second or four cycles, and the time lost in stopping is 0.08 second or five cycles. Good damping is indicated by the fact that the time lost in stopping is nearly as small as the time lost in starting.

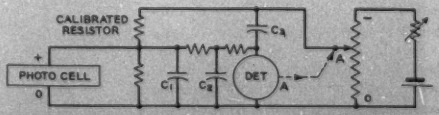
In addition to the null current range of 0.5 microampere, there have been added for convenience other current ranges and several voltage ranges by

* With an emission-type photoelectric cell it is the combination of the cell and its voltage supply which should look into a short circuit (zero voltage).

Figure 7. Circuits for microampere (null current) recorder



A—Basic circuit



B—Circuit with filtering and damping components added

means of shunts and multipliers, respectively.

A microampere recorder of this general type has been found by Dieke to work well with photomultiplier tubes for the direct intensity measurement of spectrum lines.[3] On the lower current ranges of the recorder the dark current of the photomultipliers shows up and should be balanced out or subtracted from the readings, if the use of these low ranges is to be justified.

Ratio Recorder

The microampere recorder is suited well to the study of the intensity of spectrum lines and their variations arising from all causes. For spectrographic analysis, it is desired to measure the variation resulting from change of composition of the specimen being sparked and to suppress variations from all other causes. A big step in this direction is to measure the ratio of the intensity of two spectrum lines.

Figure 9A shows in simplified form how a slidewire type of recorder can be adapted to measuring ratio. If the fixed resistor equals the slidewire, then the ratio I_x/I_s is read directly as the fractional position of the slidewire.

Several experimental recorders have been built using this basic circuit, together with a detector and balancing system about the same as that already described.

Figure 9B shows a more detailed circuit including the photomultipliers. The slidewire resistance is 5,000 ohms so that small currents from S (ten microamperes) yield adequate slidewire voltage and hence good sensitivity. The drop coil R is 25,000 ohms so that the fundamental full scale ratio I_x/I_s is 0.2. Other ratios can be read by switching the "Ayrton" shunt ratio multipliers.

The high valued resistor R_H balances the recorder slightly on scale for $I_x = 0$, which is of value when looking for small amounts of dark current. Conventional methods of doing this were not applicable because of the common terminal at battery + for I_x and I_s.

Filtering for the signal I_x is done as already described. In order that the recorder shall plot a steady ratio for fluctuating currents (of constant ratio I_x/I_s) it is necessary to filter I_s also. Furthermore, it is necessary that the two filters shall have carefully matched frequency responses.

Figure 10A, shows the record given with currents I_x and I_s of constant ratio, but with a reduction of both to one-half value, and then a return to the initial value. Figure 10B, is a record with the same recorder, made after the chart had been rolled back and rerun. The recorder is used here as a straight microammeter on I_x by supplying the slidewire from a battery. The reduction of I_x and its return to its initial value is shown. The effectiveness of the ratio method in ironing out the effect of change in absolute magnitude of the two currents is apparent.

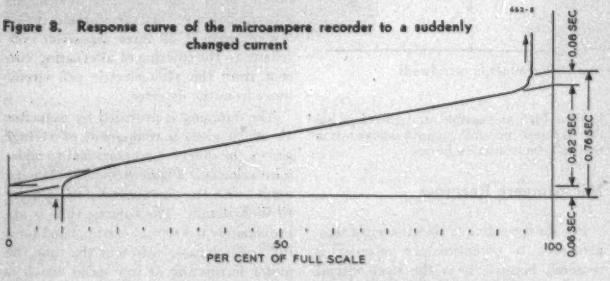
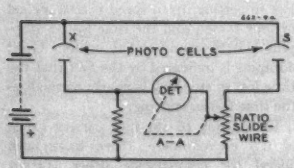


Figure 8. Response curve of the microampere recorder to a suddenly changed current



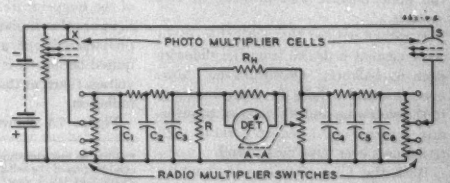


Figure 9. Circuits for the ratio recorder

A—Basic circuit
B—Circuit with filtering and damping components added

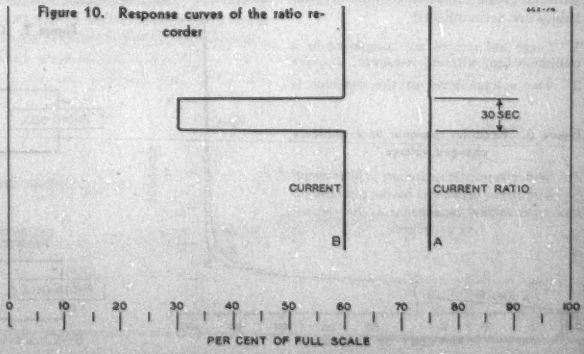


Figure 10. Response curves of the ratio recorder

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1. High Speed Multiple-Point Potentiometer Recorder for Measuring Thermocouple Temperatures During Test Flights, L. M. Stein, A. J. Williams, Jr., W. R. Clark. *Transactions* of the American Society of Mechanical Engineers, volume 66, number 4, 1944, pages 271–8.

2. Combined Thyratron and Tachometer Speed Control of Small Motors, A. J. Williams, Jr. AIEE Transactions, volume 57, 1938, October section, pages 565–8.

3. Direct Intensity Measurements of Spectrum Lines With Photomultiplier Tubes, G. H. Dieke, H. M. Crosswhite. *Journal* of the Optical Society of America, volume 35, number 7, July 1945, pages 471–80.

Radar Systems Considerations

D. A. QUARLES
FELLOW AIEE

IN the comparatively brief history of its development, the radar art has passed quickly through the general practitioner stage into the stage of many specialists. Today there are a dozen or more highly developed fields of specialization, all essential to the development of a new radar system. Each of these fields has its own basic science foundations and its engineering technology, and as soon as security conditions permit, each will have its own literature. To tie these several fields together calls for systems engineering and planning. The over-all characteristics and performance of a radar system are dependent both on the excellence of the component parts and the nicety with which they are fitted together to perform the desired function. It is the purpose of the present paper to discuss some of these systems engineering considerations, with examples of practical solutions that have been found, leaving to the specialists in the several fields the more detailed and exact exposition of their respective arts.

There have been many technical workers in this broad field, and both in England and this country they have enjoyed full interchange of technical information so that each could use the building blocks of the other as well as those of his own design. This makes it exceedingly difficult to recognize and give credit to the sources of specific contributions, and the present paper will not attempt to do so. Most of the illustrative solutions shown are the product of Bell Telephone Laboratories, but it is freely admitted that many of the basic ideas entering into these designs may have originated elsewhere. In particular, the Bell Laboratories worked very closely in this field first with Army and Navy laboratories and later with the Radiation Laboratory of the Massachusetts Institute of Technology, and in all cases there was the freest interchange of technical material. It is therefore a pleasure for us to recognize and acclaim the splendid research and development work that was done at these laboratories, even though specific recognition of their contributions seems impracticable at this time.

Antenna

The alpha and omega of a radar system are its antenna. This is true in a literal radiation sense. It is also true in the sense that the antenna was usually the first part of the system to be blocked out in plan and the last part to be completely frozen in design. This antenna problem is familiar to radio engineers, but in modern radar where the same antenna is used both to transmit and receive, its characteristics have an even more profound influence on the performance of the system. The simplest radar antenna resembles a searchlight in that it consists of a suitably shaped reflector illuminated by one or more sources of electromagnetic energy. If the reflector is a paraboloid of revolution with the source at its focus, the radiation is of the single lobe or beam variety in which the angular width of the beam is inversely proportional to the diameter of the reflector and directly proportional to the wave length of the radiation. While such a beam antenna has been extensively used, many of the more recent radar systems have demanded more specialized radiation patterns. For example, in airborne search and bombing radars, a fan-shaped beam has come to be considered optimum. At any one position, such an antenna illuminates a narrow wedge of the terrain below, extending, ideally, from the point of the terrain vertically beneath the plane out radially to the maximum effective range of the system. The design objective here is to produce as narrow a beam as possible with a vertical pattern such that substantially equal signals are received at all ground ranges. This requires that the effective voltage be approximately proportional to the square of the cosecant of the vertical angle measured downward from the horizon. A more recent and as yet unpublished study of this problem has indicated that some modification of this cosecant squared

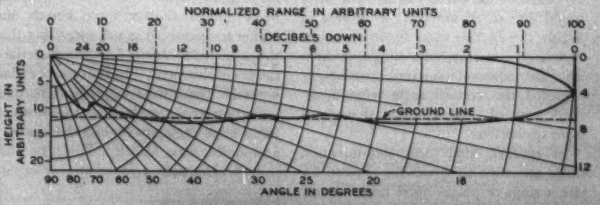
NORMALIZED RANGE IN ARBITRARY UNITS
0 10 20 30 40 50 60 70 80 90 100
DECIBELS DOWN
0 24 20 16 12 10 9 8 7 6 5 4 3 2 1 0
HEIGHT IN ARBITRARY UNITS
0 5 10 15 20
0 4 8 12
GROUND LINE
90 80 70 60 50 40 30 25 20 18
ANGLE IN DEGREES

Figure 1 (above). Vertical antenna pattern (airborne radar system)

Figure 2. Oscilloscope picture of Cape Cod from 19,000 feet (range circles are spaced at five miles)

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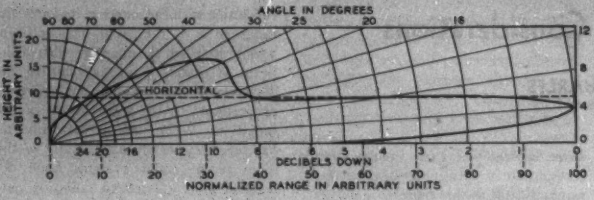

ANGLE IN DEGREES
90 80 70 60 50 40 30 25 20 16
HEIGHT IN ARBITRARY UNITS
HORIZONTAL
DECIBELS DOWN
NORMALIZED RANGE IN ARBITRARY UNITS

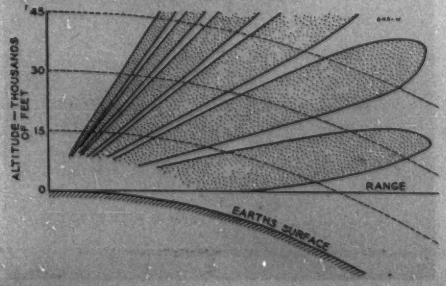
Figure 3. Vertical antenna pattern in free space (land-based search radar system)

formula may be advisable. In any event, the fair approximations to the ideal that it has been possible to achieve in actual design give satisfactorily uniform ground illumination. For example, the vertical pattern of the final stage of antenna evolution of a radar set used for search and bombing purposes in B-29 planes is shown as Figure 1. Figure 2 shows that quite satisfactory uniformity of ground illumination was achieved by this vertical pattern.

Other variations on antenna pattern include beams very much sharper in azimuth than in elevation for airplane search purposes and the reverse for height-finding purposes. One of the latest refinements here is illustrated by a typical vertical antenna pattern of a recent land-based air search antenna, as shown in Figure 3. In this case, in order to get high angle coverage, something approaching the cosecant squared pattern is achieved, the vertical angle being measured upward rather than downward from the horizon.

In general, land- and ship-mounted radar sets used to search the horizon for either ships or planes must take account of the fact that the intervening land or water surfaces reflect that part of the radiation directed below the horizon. Combination of the direct and the reflected waves produces a characteristic interference pattern in the vertical plane, greatly extending the range of the radar system at certain elevation angles and correspondingly reducing it at intermediate angles. A typical vertical performance or coverage chart of a light early-warning system is shown as Figure 4. In this case the beam in free space is fan-shaped with a horizontal width of about 3.5 degrees. The horizontal pattern is not greatly affected by the surface reflection, while the vertical pattern shows the very sharp lobes resulting from direct and reflected wave interference.

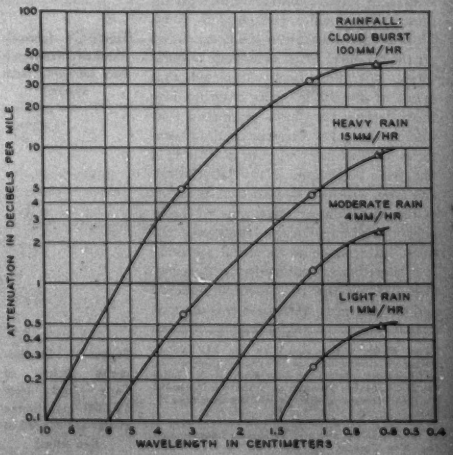
Figure 4. Vertical coverage chart (land-based radar system at a low site overlooking water)



Frequency

Since the whole trend of radio development in the past two or three decades has been toward shorter wave length and higher frequency, it is not surprising that the same trend should have characterized radar development. In the case of radar, however, there were considerations over and above those applying to radio, which put a large premium on higher frequency and shorter wave length. This is because radar is essentially a seeing and measuring art, and fineness of vision and precision of measurement are related directly to fineness or shortness of wave. This, of course, comes about from the fact that with an antenna of given physical dimensions, the spread of the beam is proportional to the wave length, other things being equal, so that as the beam sweeps through an angle, its ability to discriminate between two nearby reflecting objects is an inverse function of the beam width. The above assumes that the two objects are at equal range. If, on the other hand, they are on a line with the radar antenna but at unequal range, the ability of the radar set to discriminate between them is an inverse function of the pulse length. It follows from the above broad reasoning that each radar set will be characterized by a figure of confusion in space, the cross-section of which is directly related to the beam height and width and the depth of which is directly related to pulse length. Within this figure, multiple reflectors will appear as one. Reflectors that cannot be encompassed within such a figure of confusion, on the other hand, would be resolved. Actually, certain characteristics must be met in other parts of the radar system, notably in the intermediate-frequency (hereafter referred to as i-f) and video amplification and in the cathode ray tube properties, in order to realize the theoretically possible discrimination provided by the radiation system. It is quite practicable, however, and in fact common practice, to design the rest of the system so that the discrimination of the radiation system is limiting. Since, with fixed antenna size, beam width is directly pro-

Figure 5. Effect of wave length on attenuation caused by rain



portional to wave length, it follows that to achieve high resolution or high discrimination, radar had a very special reason for seeking higher frequencies and the same reason for preferring shorter pulse lengths even though the latter, in general, meant a sacrifice in range. Actually, early radar sets made the best use of prewar technology and employed wave lengths down to about one meter. In four fairly discrete steps, this wave length was reduced successively to bands in the neighborhood of 40, 10, 3, and 1 centimeter. This change was accompanied by the use of shorter and shorter pulses so that the over-all effect of the development was to decrease the volume of the figure of confusion by about five orders of magnitude, two each for height and width and one for depth. As in so many other trends of this kind, these advantages were not gained without penalties. In fact, in the case of the shortest wave length mentioned, atmospheric absorption and raindrop interference get to be such serious limitations as to appear to restrict this and shorter wave lengths to only very special uses. Figure 5 shows the relation of attenuation to precipitation at different wave lengths, and Figure 6 shows the effect of energy absorption by gaseous components of the atmosphere. If this restriction proves real and permanent, it appears that the useful free space spectrum has now been explored and, in fact, is rapidly being conquered and settled.

Transmitter

The two principal elements of the transmitting system are the radio-frequency oscillating tube and the source of high-voltage pulses, variously called a keyer, modulator, or pulser. It is the function of the latter to deliver to the oscillator tube square-topped spurts or pulses of very high voltage of the order of a microsecond in length and spaced of the order of a millisecond apart, these specific values varying over considerable ranges according to the specific purposes of the radar equipment.

Two basic methods have been used to form the microsecond pulses:

1. Short-circuiting or open-circuiting a charged artificial transmission line, often called a pulse network.
2. Creating large-voltage surges by driving a magnetic circuit into the region of saturation.

In connection with 1, the switches used to open- or short-circuit the charged pulse network have been

1. High-voltage vacuum tubes.
2. A spark-gap discharge either of the open air or enclosed type.
3. The hydrogen filled thyratron.

Since these several forms of modulators will be described in detail by others, suffice it to say here that all of them were applied extensively in operating systems, with recent design tending toward a preference for the hydrogen thyratron.

During the brief interval of the pulse, powers ranging up to the order of a megawatt may be delivered by the pulser. Since the particular combination of current and voltage put out by the pulser may not be that required by the oscillator, it is common to interpose a pulse transformer, the function of which is to step the voltage up or down to the desired level. In some radar systems, a transmission line is required between the pulser and its associated transmitter, in which case pulse transformers may be required at each end of the line. A typical oscillogram of the magnetron input current as a function of time, delivered by a hard tube modulator used extensively in airborne

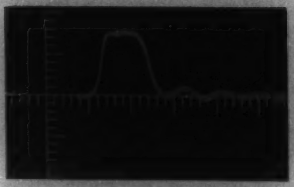
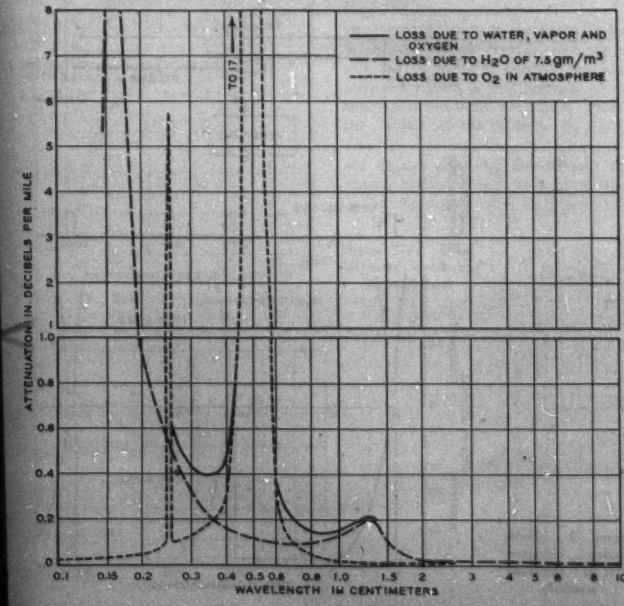


Figure 7. Magnetron input current delivered by hard tube modulator

3/4 μsec, 800 pulses per second
Magnetron current = 4.5 ma average
= 14 amp peak
Rise time = 0.03 μsec
Pulse width = 0.42 μsec
Pulse scale = 0.07 μsec per division

Figure 8. Magnetron frequency spectrum (scale = 10 megacycles per division)

Figure 6. Effect of wave length on attenuation caused by gases in atmosphere


LOSS DUE TO WATER, VAPOR AND OXYGEN
LOSS DUE TO H_2O OF 7.5 gm/m³
LOSS DUE TO O_2 IN ATMOSPHERE
TO 17
ATTENUATION IN DECIBELS PER MILE
WAVELENGTH IN CENTIMETERS

systems, is shown in Figure 7. The frequency spectrum produced by this pulse is shown on Figure 8.

Various forms of more or less conventional triodes found application as transmitting oscillators in the earlier longer wave radar sets. In this class of tube, time of flight of electron from cathode to plate must be short compared with the signal period—an increasingly serious limitation as the art moved into the microwave range. Velocity modulation tubes avoid this limitation in a sense by making use of the electron stream in flight. A particular form of velocity modulation tube, the cavity magnetron, has virtually monopolized the transmitting oscillator role in the more modern systems. In fact, its adaptation to very high power, very short pulse operation, and its very high frequency stability make it ideally suited to this purpose. In earlier forms, the magnetron was a fixed frequency device, but more recently external means of tuning over a moderate range have been devised and applied in practical design. While the frequency of the cavity magnetron is largely controlled by its built-in cavity construction, it is, of course, necessary to couple the oscillations in the internal cavities with the output line, and the reaction on the magnetron of this coupling imposes some neat problems of system design. As the antenna scans, the impedance facing the magnetron varies on account of varying reflections from discontinuities such as rotary joints in the output line to the antenna. These effective impedance changes, reflected back into the magnetron through its output coupling, tend to modulate or pull the frequency of the magnetron. Maximum power output calls for tight coupling between the magnetron and its antenna system, but such tight coupling in turn accentuates this pulling effect. In addition, there is a "long line" effect which causes an impedance irregularity to be more serious the longer the transmission path between it and the magnetron. Practical system design makes it necessary to take all of these factors into account and to tailor the characteristics of the magnetron to the degree of smoothness and excellence it is practicable to achieve in the radio frequency transmission system.

Duplexer

One of the most important practical contributions to radar design was the development of duplexer methods making it possible to use the same antenna for both transmitting and receiving purposes. Since the outgoing radar pulse occupies a very small fraction of the time, characteristically about one-tenth of one per cent, a switch which would associate the transmitter with the antenna during this brief interval and then disconnect the transmitter and connect the receiver during the relatively long silent interval, was called for. Since the total cycle, however, was only of the order of a millisecond, a very fast switch was required. In practical design, a gas-filled "TR" tube was almost universally used for this purpose. It is obvious that the requirements that this tube protect the receiver during the very high power transmitting interval and that it recover rapidly enough to admit echoes from nearby targets and thus achieve the desired minimum range for the system made it a very important element. Figure 9 shows the transmission characteristics of a typical "TR" tube assembly as measured in the transmit and receive paths over one complete pulse cycle.

Receiver

From our present point of view, the most significant elements of the radar receiver in order in the circuit are the beating oscillator, the detector, the i-f amplifier, followed by a second detector and video amplifier, and finally the display system. While each one of these elements has its own peculiar art, there are certain broad systems considerations. For the early long wave length radar sets, beating oscillators were of the more or less conventional triode construction. In fact, one very special triode, the so-called lighthouse tube, has been used as a beating oscillator up into the microwave range. As in the case of transmitting oscillators, velocity modulation has been the key to the design of most of the receiving or beating oscillators used in microwave systems, and for the most part, these have been of the single-cavity built-in type. The earlier forms had fixed or manually tuned cavities and beyond this, were tunable within a fairly narrow range by adjustment of the voltage of the repeller electrode. Not only was this voltage adjustment used for narrow range manual tuning of the receiver to its transmitter output, but automatic frequency-control circuits employing an intermediate frequency-discriminator circuit were devised which regulated the repeller voltage at the proper value for reception of echoes of the transmitted pulse. These automatic frequency-control circuits were not without their difficulties, but various improvements were introduced so that those embodied in most recent systems were quite stable and satisfactory. A typical

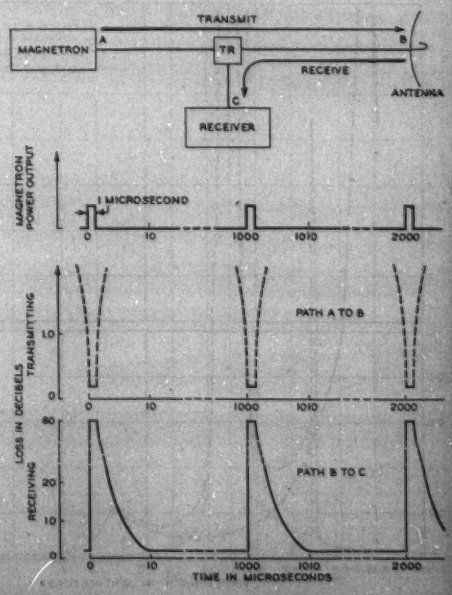


Figure 9. Transmission characteristics of "TR" tube assembly

Figure 10. Typical velocity-modulated beating oscillator

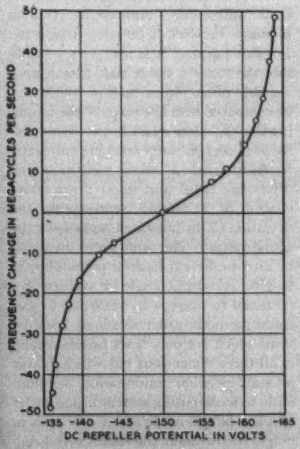


Figure 11. Beating oscillator electronic tuning

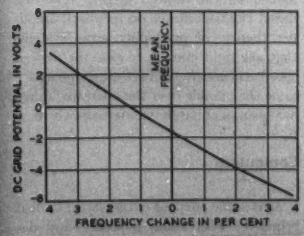


Figure 12. Beating oscillator thermal tuning

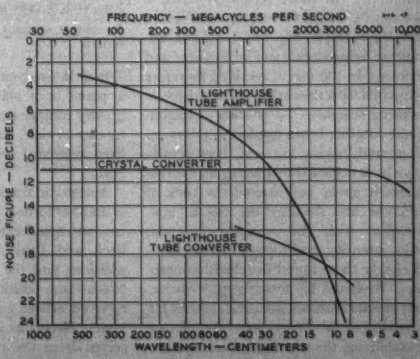
velocity-modulated beating oscillator with built-in cavity is shown as Figure 10, and the relationship between frequency and repeller voltage is shown as Figure 11.

More recently, thermal means of controlling oscillator cavity size have been devised, the heating effect being regulated by a control voltage. A typical relationship between this thermal control voltage and oscillator frequency is shown in Figure 12. Where thermal control of this type is available, automatic frequency control may be built around it rather than resorting to repeller voltage control as in the earlier systems.

First Detector (Converter)

In a radar system, the selection of frequency is based among other things on the noise figure available in the receiver. The input circuit of the receiver is the low-signal level point of the system, and the problem here has been to achieve the greatest possible freedom from noise. The longer wave radar receivers employ a combination of vacuum tube pre-amplifier and detector to achieve the best noise figure. In general, however, crystal detectors of the fixed cat's-whisker-on-silicon type have been almost universally used at wave lengths of about 30 centimeters and less. Figure 13 shows a comparison between the noise values of the lighthouse tube as an amplifier or detector, and the crystal-type detector. A great amount of development work has been done on these crystals, with the result that a uniform product has been achieved within a few decibels of the theoretical resistance noise limit. While the crystal is not strictly frequency-sensitive, optimum design calls for different crystal units for the different frequency bands. Means must be provided in the system to protect the crystal from high-voltage overload which would destroy its sensitivity.

Figure 13. Effect of wave length on receiver noise



Intermediate Frequency

Choice of intermediate frequency rests on a number of factors, including signal-to-noise ratio and band width. About 90 decibels of i-f gain is required with a band width of from one to ten or more megacycles. Since resistance noise (power) is proportional to band width, the early tendency was to make i-f amplifiers as narrow as possible consistent with the pulse length to be accommodated. In more recent systems, there has been a trend toward wider band receivers as a means of sharpening up the picture. While, for example, a one-megacycle i-f system followed up by a one-half-megacycle video system would be expected to give approximately the optimum signal-to-noise ratio for a radar set employing a pulse of about one microsecond, it has been found in certain types of display that considerable advantage can be had by widening the band by a factor of as much as five. In such cases the increased noise is more than offset by the greater sharpness of the signal and by the finer grain structure of the noise.

Actually, most of the i-f amplifiers have been designed around a frequency of either 30 or 60 megacycles, but it would go beyond the scope of the present paper to discuss the relative uses and advantages of these two intermediate frequencies. Great progress has been made in achieving very low noise amplification and in producing the desired gain and gain frequency characteristic with a minimum of tubes and other components. The development of the 6*AK*5 high figure of merit miniature pentode was a great boon to i-f amplifier designers. Figure 14

attached shows an i-f strip employing six 6AK5 tubes and giving a gain of 65 decibels at a band width of 13.5 megacycles, centered at 60 megacycles. The design of the second detector and video amplification circuits is closely related to the television art and perhaps deserves no further comment in this paper.

Figure 14. Typical i-f amplifier assembly

Display Circuits

The cathode ray tube has been substantially without a competitor for radar display purposes. A variety of display techniques has been developed, and a variety of cathode ray tubes of several sizes and of several different phosphors has been developed to meet the needs of radar systems. Rather than trying to tabulate these several varieties and their uses, the systems problem will perhaps be best illustrated by taking one of the most important combinations and examining its characteristics in relation to over-all performance. For this purpose, we choose a high-persistence so-called cascade phosphor and operate the tube as a plan-positon indicator in which each sweep is radial from the center to the outer edge and the direction of the sweep rotates like the spoke of a wagon wheel, at any instant the direction corresponding to the direction in space of the scanning antenna. The beam is intensity-modulated by the video signal, and the radial sweep is timed to correspond to the outward sweep in space of the radar pulse. In such a display, therefore, signals are shown on the face of the tube in their plan position relationship in space, the center of the tube normally corresponding to the position in space of the radar set. Here, again, the problem is not unlike that of a television receiver scope except that in the plan-position indicator type of display, a different scanning system is employed. In most recent systems, a permanent magnet focusing mechanism has been employed, the principal advantage being stability of adjustment and economy in the use of rectified power as compared with the earlier electromagnetic focusing scheme. To produce a wagon-spoke rotating beam needed to follow an all-around-looking antenna, best results have been achieved by placing an electromagnetic sweep coil around the neck of the tube and rotating the coil in synchronism with the scanning antenna. Gain, intensity, and focus controls parallel closely those found in television practice. It should be noted here, however, that special features such as facilities for expanding desired portions of the picture or stabilizing the picture against motions of the mother plane or ship have been devised and afford very important improvements in certain display systems. Methods also have been devised for discriminating between fixed and moving targets. These methods are of great importance in search systems where echoes from distant planes tend to be masked by permanent echoes from mountains or other features of the terrain.

Fire Control Radar

The above discussion deals primarily with radar as a search device. Many of its most important military applications, however, go beyond this search or seeing function to the more precise measuring function of fire control. In general, a radar fire control system must perform the following functions:

1. Precise three-co-ordinate location and tracking of the present position of the target.
2. Prediction of the location of the target at some future time, for example, the time at which a projectile would cross its path.
3. Generation of control orders, such as signals, to train and elevate the gun, set the fuse, and, in general, control the fire.
4. Servo systems for carrying out these orders.

When the fire control system is located on a plane or a ship, these problems are greatly complicated by the motions of the mother vehicle, calling in turn for stabilized reference systems and much other gear.

Automatic tracking is achieved by one or another form of lobe switching in which the antenna beam is rapidly switched back and forth between two angular positions and the target is centered between these positions by making the two received echoes equal. In fact, a servo system having as its input the echoes received from the two lobes can then be made to drive the antenna to a position where the two echoes are equal, and thus continuously adjust the antenna to such a position as the source of the echo moves. A variation on lobe switching in which the antenna conically scans, makes it possible to center the antenna in both azimuth and elevation and similarly uses two servo systems to track automatically in both dimensions. Automatic tracking in range involves a different technique. For this purpose, it is necessary to build into the radar a range unit producing a variable range pip or marker which may be compared with the range of the incoming signal. Here again it has been possible to make this range tracking automatic by employing a servo system which drives the range unit up or down under control of a voltage representing the deviation of the indicated range from the actual range. The same servo drive can be used to drive a shaft or potentiometer to give an output angle or voltage proportional to range. By resorting to precision methods, radar sets have been devised which not only track automatically in all three dimensions but which deliver present position information continuously to a computing system to accuracies of a few mils in angle and a few yards in range, this without the target ever being visible and, in fact, without human assistance once the radar equipment is locked on the desired target. The art, based fundamentally on feedback amplifier theory, of producing servo systems that are tight enough to give the desired speed and accuracy of response and at the same time stable over the operating range has been adequately treated elsewhere.

Computers

As it is the purpose of this paper to deal primarily with radar systems, any detailed discussion of computers would be

Figure 15. Computer used with airborne bombing radar

beyond its scope. It is pertinent to point out, however, that association with computers in a fire control system has a profound effect on the requirements to be imposed on the radar system proper. A more detailed consideration of one particular combination of radar and computer would illustrate this point. In a radar bombing system, fire control becomes bombing plane and bomb control. The computer, as before, has as inputs present-position information about the target. It must predict the future position of the target, the time interval being that required for the bomb to fall from the plane to the ground. The fire control orders in this case are directions to the pilot or to the automatic flight control equipment as to the proper course for the bombing plane and directions to the bomb release mechanism as to the instant in the plane's flight at which the bomb should be released. Such a computing mechanism must also be given as inputs the altitude of the plane and the ballistic characteristics of the particular bomb to be dropped. These are either previously known or separately determined and set into the computing mechanism in advance. Here again a great amount of development work has been done to improve the practicability and accuracy of the system and to make the best use of the not too adequate radar data available. The complexity of the problem and of the equipment required to solve it is perhaps best indicated by the photograph, Figure 15, of a bomb sight computer developed and introduced in radar bombing shortly before the termination of hostilities. Without attempting to explain the mechanism, suffice it to say that this computer performs the following operations: In association with a radar system displaying before the bombing operator a plan-position indicator type of "map" of the target terrain, the operator tracks by centering electronic range and azimuth markers on the "target." This tracking process not only feeds present position into the computer but at the same time enables the computer to determine the essential forward and transverse rates of the plane. Into the computer will previously have been set the ballistic constants of the bombs to be dropped. The height of the plane above the terrain will have been determined by a prior range tracking on the nearest ground return which would come from that vertically beneath the plane. Using these input data, the computer will predict the future position of the plane at an interval equal to the time-of-fall of the bomb; it will set up steering orders, either to the pilot or through the automatic flight control equipment, to move the plane into the correct position and heading; and it will give a bomb release order or control signal to operate the release mechanism at the correct instant. In the particular equipment shown, the computations assume level, steady flight, a limitation which it would require considerable additional gear to remove. This computer does, however, afford one very important additional facility, namely that of offset bombing. Because of the coarseness of radar data, information about the terrain is at best not too good. Certain landmarks do stand out sharply, and the geographical relation of these to strategic targets may be known or determined by reconnaissance. The ability to track a radar landmark and bomb a target of known range and azimuth offset from the tracking point greatly increases the flexibility of the equipment. The computer shown provides this feature, so that, having set in known offset co-ordinates, the operator proceeds as though to bomb the aiming point, the computer making the corrections and actually directing the attack against the target.

Radar bombing systems cover a wide range of weight and complexity and require nice judgment to reach a fair balance between such factors as operating facility and precision on the one hand and equipment bulk, reliability, and other "price" factors on the other. Enough progress has already been made to assure that highly flexible and precise radar bombing systems will become available at a "price" that is in reasonable balance with other factors.

Any discussion of radar systems would be incomplete if it failed to touch on the all-important question of testing and test equipment. Actually, the practical success of radar in the field was largely dependent on the provision of adequate specialized test gear. This was an art in itself, the treatment of which is reserved for a companion paper.

This paper will have served its purpose if it gives a technical background for the more detailed exposition of the many-sided art that is modern radar. Security will probably continue to limit workers in this field in the telling of their story, but it will be possible to tell enough to indicate clearly the truly wonderful advances in electronic and related arts that have brought radar to its present stage of development.

A New Wire Recorder Head Design

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Synopsis: Certain defects inherent in the usual design of wire recorder heads are pointed out. Some defects are of a practical nature and one is based on theoretical considerations. An improved design is proposed on which a limited amount of experience has been obtained. A natural modification of this design permits level-winding across the record-playback head, thus distributing the wear and resulting in a head that is virtually self cleaning.

WORK with wire recording during the past few years seems to have been confined to two general types of heads for recording, playback, and erase purposes.[1] These are illustrated to a somewhat enlarged scale in Figures 1 and 2. Figure 1 shows two variations of the so-called open type of head in which the recording wire runs over a grooved pole piece, and Figure 2 shows a closed type of head in which the relation between the recording wire and the pole piece is substantially the same as in Figure 1, but in which the exciting coil surrounds both the pole piece and the wire.

Certain combination heads have been developed which combine the functions of record and erase in one structure. These always use separate gaps for the erase and the record operations. Playback is over the record gap. The structural modifications seem obvious and are not shown. The principal difference between a record or playback head and an erase head is that the latter ordinarily uses a gap of about 0.010 inch, and the playback gap for a wire speed of two feet per second is preferably about 0.0015 inch.

Figure 3 shows the relative record-and-playback characteristics for the open and closed type heads. A qualitative analysis of the situation that causes this difference between open and closed type heads has been given by Holmes and Clark.[1] According to this analysis, the so-called stray field is responsible for the irregularities, since the phase relation between the stray field and the main field depends on the frequency and the wire speed. It should be pointed out that a closed head greatly reduces the effect of stray fields, since the leakage flux has to go through the coil to contribute any adverse effect (on playback).

Figure 4 is a photograph of an equipment that has been set up to study experimentally the characteristics of various types of heads. This is arranged so that it can be operated on a continuous loop of wire about 20 or 30 feet long, or so that it can be operated from spool to spool. Provision is included for various speeds from 1.25 to 5 feet per second. The playback head is located a few feet along the wire from the record head so that in listening tests it is possible to get a quick comparison between a few bars of music as recorded and as played back. This almost instantaneous playback is very useful in collecting data, especially when working from spool to spool.

The first heads used on this equipment were of the closed type but in which the operating gap was adjustable. An optical system was used that made it possible to project on the wall of the room a 150-diameter enlargement of the operating gap and the wire traveling through it.

One of the first things discovered with this equipment was that the gummy residue that accumulates on the heads is a magnetic mud that has a shunting effect on the working gap. This seems to be of little consequence at low frequencies, but the effect at 5,000 cycles may be as great as 15 decibels or more, for a two-foot-per-second wire speed.

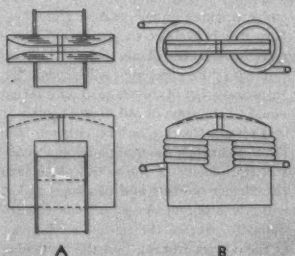

Figure 1. Open type record-playback head

A—High impedance head with laminated magnetic structure

B—Low impedance single lamination head, used with step-up transformer on playback

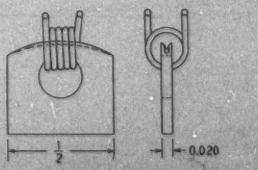

Figure 2. Closed type single lamination record-playback head

Lamination thickness is exaggerated

It was found that by frequent cleaning with carbon tetrachloride, quite consistent results were possible, even at high frequencies. It seemed apparent that in more conventional head designs there would be little trouble from this accumulation of magnetic mud, since the operating gap is filled with solder. The actual event however was contrary to this wishful thinking.

By lifting the wire a little as it moved through the gap and observing the enlarged image on the wall, it was determined that at low frequencies it made no difference where the wire was in the gap until the wire started to leave the region between the sides of the groove. At high frequencies (5,000 cycles), however, the smallest motion perceptible in the enlarged image on the wall, corresponding to about 0.0002 inch at the gap, made a difference in playback of about three decibels. These tests were made at the playback head, since there was no time lag there between cause and effect. Subsequent experiments show that for high frequencies the effect at the record head may be even more pronounced.

It is an unfortunate fact that this magnetic mud frequently will build up underneath the recording wire, even with substantial tension in the wire and working over a small radius such as one-fourth inch. This causes the actual performance of such a system to be rather uncertain above about 2,500 cycles, at least for wire speeds on the order of two feet per second.

By the simple expedient of using sufficient carbon tetrachloride and using it often enough, it is possible to keep the grooved type of heads fairly clean. But this has caused another sort of trouble, since with no lubricant whatever the wire may abrade the head sufficiently to cause a 6- or 7-decibel increase in the noise level. This noise level evidently is due to microphonic action of the head. In such cases a drop of oil on the head will bring the erase noise level down about three decibels in the first minute, and another three

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or four decibels in a few more minutes.

Another minor disaster that may happen with the grooved type of head is that after running for quite a while on wire that is 0.004 inch in diameter some wire may come along that is 0.0042 inch in diameter. The least that will happen is that the wire will bind in the head. This may cause repeated breakage of the wire, and certainly will introduce a pronounced kinkyness on account of cold working one side of the wire

This also may cause a substantial change in the magnetic quality of the wire and the partial loss of any recording then on it. Unless the wire is run with an unusual amount of tension the curliness alone caused by such an accident will preclude further use of that particular section of wire. It is true that such things do not happen often but they are vastly annoying when they do happen.

This raises a question as to the practicability for home or school use of any head that depends for its performance on running the wire at the bottom of a groove, unless some means can be devised to insure intimate contact between the wire and the pole pieces. A suitable method should preclude the possibility of the binding action just described. The tendency of mud to accumulate under the wire is a factor that must be overcome by eliminating the mud or redesigning the head so it will be easy to clean.

Magnetic Considerations

It can be shown (see appendix) that for small values of lamination thickness or cylinder diameter, the flux penetration is less in the lamination. By an extension of the idea that the flux penetration is a function of the curvature of the surface penetrated, it follows that the penetration will be even less into a concave surface than into a plane surface, and this decrease of penetration will be marked particularly when the concave surface has a small radius, such as 0.0025 inch.

These considerations make it appear that the conventional head design in which the recording wire runs at the bottom of a narrow groove is not a good design magnetically, unless the laminations are so thin that skin effect is not appreciable.

Since satisfactory operation requires a biasing magnetomotive force in the record gap having a frequency as high as 20 to 40 kilocycles, the required laminations would be around 0.005 thick if of conventional high permeability alloy, and a design that would be satisfactory from mechanical considerations becomes difficult. An alternative solution would be to use a low permeability alloy or even powdered iron. However, such a step would reduce the playback efficiency somewhat, and it is not clear that there would be any net gain, even if the bottom of the groove could be kept clean.

It is reasonably clear that the magnetic requirements for a good record head are somewhat opposed to those for a good playback head, since in the latter case skin effect in the magnetic structure is of no importance and a material of maximum permeability would be most desirable. In the record head any reduction in permeability without reducing the saturation flux density reduces the skin effect and therefore reduces saturation effects.

There is clear evidence of saturation in the record head at levels below that at which saturation occurs in the wire. This is shown by Figure 5A, which is a plot of the playback response versus record bias at several record frequencies, and on a conventional closed type head. The fact that the bias for maximum response decreases as the frequency increases is a clear indication of saturation in the record head. Without saturation in the record head all record frequencies would show maximum playback at the same value of bias.

Minimum third harmonic distortion is obtained at that bias that gives maximum low-frequency response, and in other frequency response curves given here, the bias has always been set at the lowest value consistent with maximum response at 500 cycles.

New Head Design

As a result of these considerations it seemed worth while to try a head design on the order of that shown in Figure 6.

Figure 3. Playback characteristic taken with closed type record head

O—Open type playback head
●—Closed type playback head

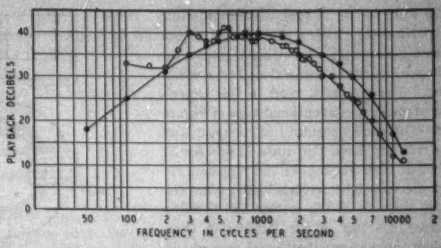
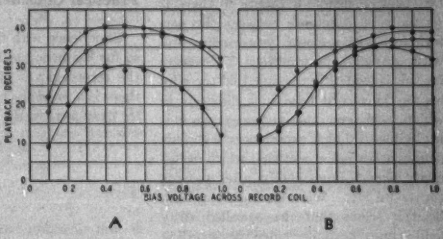


Figure 4. Experimental equipment for record and playback studies

Figure 5. Record-playback characteristic versus high frequency bias voltage, using closed type playback head

A—For closed type record head
B—For new type open record head
O = 500 cycles
◐ = 2,000 cycles
● = 5,000 cycles



We were forced to that conclusion while experimenting with a record head of the same general type but with a groove for the wire to run in and a closed type winding. The playback head in this experiment was the conventional type of Figure 2. The results seemed quite erratic, and in running down the cause it was found that at high frequencies the playback response was eight decibels higher when the wire was out of the groove and running across the top of the lamination than when the wire was bottomed properly in the groove. The single lamination used was about 0.060 inch thick, the groove about 0.030 deep including a shallow V at the top, and in operating on a continuous loop the wire frequently would not return to the groove after the knot went past.

It was found by using a head of the type shown in Figure 6 for record purposes, that with either an open or a closed type of winding it substantially duplicated the performance of the conventional closed type head of Figure 2 when used with stainless steel wire of moderate coercive force (around 175 oersteds) and usual retentivity. With this type of head (of Figure 6) there is virtually no difference between the performance with a closed type winding and with an open type winding. The reason for this is evidently the fact that the wire leaves the record head in a direction in which the magnetomotive force gradient is negligible so that it experiences negligible demagnetization except that which necessarily occurs immediately after passing the record gap. When used as a playback head it seems that the so-called stray field is quite negligible since the recording wire is running substantially tangent to a cylinder. See Figure 7A for playback response on closed type head for closed type and new open type record heads compared on the same loop of wire.

In recording with the same head on a wire that had a coercive force of about 250 oersteds, it was found that in the high frequency range the playback response was up to 10 decibels higher than with the head of Figure 2. In fact, it was so good that if the frequency range of interest is limited to 7,000 cycles[3] at the upper end, there is no point in doing much high frequency equalizing. Figure 7B shows the same sort of comparison as Figure 7A, but for wire having a coercive force of 250 oersteds.

It perhaps should be pointed out that this improvement in high frequency response depends on the production of a high coercive force wire. Without this there is no appreciable gain at high frequency except in reliability, and there

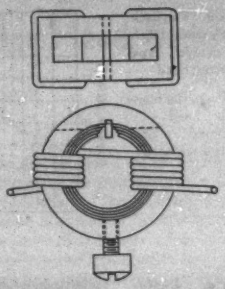


Figure 6. New design of open type head that is easily cleaned and magnetically efficient

may be a net loss of one or two decibels at frequencies on the order of 100 cycles.

The same construction is applicable to erase heads, but in this case it becomes important to use a bakelite receptacle rather than the brass ring shown. The high frequency erase current is sufficient to generate substantial heat in the brass ring.

Practical Considerations

Experience with this new type of head so far has been most instructive. When the record gap is filled with soft copper there is a pronounced tendency for metal to drag across the gap from the pole pieces, and eventually to shunt the gap. There seems also to be a tendency to undercut the copper. These two factors explain the short life occasionally experienced with the grooved type of head in which the working gap is filled with solder as a usual practice.

It would seem desirable to fill the gap with something that would wear away more slowly than the pole pieces, and hardened beryllium copper has been used for this purpose, with satisfactory results to date.

The most significant advance involved in this new type of head is that it is a very simple head to clean and keep clean. Our experience indicates that there is no way to obtain reliable performance at desirable wire speeds without virtually eliminating dirt from the record and playback heads. Eliminating dirt from the erase head is also desirable but not so critical on account of the wider gap (about 0.010 inch).

With a head design in which the operating part of the head is an element of a cylinder the possibility of level-winding across the head naturally suggests itself. This would result in playing the recording wire back and forth along the length of the working gap (the wire crosses the gap at right angles) and this would distribute the wear and at the same time help keep the working surface clean. Figure 8 shows an experimental design of such a

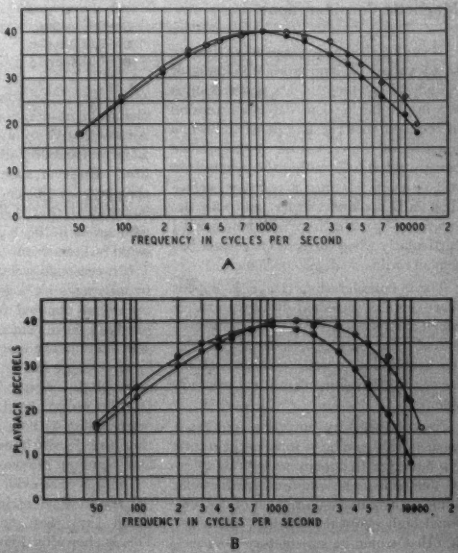


Figure 7. Comparison of closed type and new open type record heads

Playback head was closed type. Wire speed two feet per second

O—New open type head

●—Closed type head

Wire characteristics: A—H_c 180; B_r 5,900

Centimeter-gram-second units; B—H_c 250; B_r 4,650

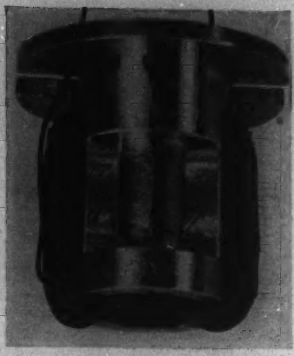


Figure 8. Experimental model of level-wind head with open type winding

This has been modified from the design of Figure 6 by lengthening the record gap along the axis of the cylinder

head in which the wire plays back and forth one half inch as the level-wind travels in and out.

Experimental results to date on this level-wind type of head have been completely satisfactory. Response data indicate the same performance as for the head illustrated in Figure 6.

Conclusions

Certain defects of a practical nature have been found in heads of conventional design. These defects seem to be inherent in the design of these heads and the nature of the problem.

Improved designs have been tried experimentally and their performance verified as far as electromagnetic characteristics are concerned.

There has not been time enough for the experience that is required to establish their practical merit beyond any question, but the nature of the change makes their practical merit seem very likely.

On the experimental equipment shown in Figure 4, a maximum range between saturation and erase noise level of 45 decibels is obtained regularly. This corresponds to a usable dynamic range of about 40 decibels. The quality is comparable to vertically cut vinylite records.

It has been shown quite clearly that the new design reduces magnetic saturation effects at the record head. It should therefore reduce cross modulation effects.

In those cases in which the level-wind feature can be sacrificed, the possibility is presented of accomplishing tone control in a very simple manner. It would be necessary only to taper the playback gap from say 0.0015 to 0.003 inch and shift the recording wire to the wider part of the gap to eliminate the higher frequencies in the playback.

Appendix

Practical units and inch dimensions are used in the work that follows, except that ρ is given in microhms per centimeter cube corresponding to usage in tables. Let

r = radius in inches to cylindrical element of radial thickness dr or distance in inches from center plane to plane element of thickness dr

r_1 = outside radius in inches of magnetic cylinder or half thickness in inches of magnetic lamination

μ = relative permeability

f = frequency in cycles per second

ρ = resistivity in microhms per centimeter cube

B = flux density at dr in lines per square inch

B_1 = flux density at r_1 in lines per square inch

ϕ = integrated flux from unit length of periphery to center line or plane

$m = 0.505(\mu f/\rho)^{1/2}$

K = effective flux penetration in inches/$1.4(\rho/\mu f)^{1/2}$

$x = mr$

$y = mr\sqrt{2}$

$z = 2mr$

It can be shown that the differential equation of alternating magnetic flux distribution into a cylinder is[4]

$$\frac{d^2B}{dr^2}+\frac{1}{r}\frac{dB}{dr}-2jm^2B=0 \qquad (1)$$

if the direction of the magnetic flux is parallel to the axis of the cylinder. The same equation obtains for the penetration into a lamination of flux parallel to the lamination, except that in this case the coefficient $1/r$ of the first order term is zero.

For the solid cylinder the solution is

$$B=B_1(\text{ber } y+j\,\text{bei } y)/(\text{ber } y_1+j\,\text{bei } y_1) \qquad (2)$$

For the lamination the solution is

$$B=B_1\frac{(\cosh x\cos x+j\sinh x\sin x)}{\cosh x_1\cos x_1+j\sinh x_1\sin x_1} \qquad (3)$$

The corresponding equations for the integrated flux from unit length of periphery to the center line of the cylinder or to the center plane of the lamination are

$$\phi=\frac{B_1}{2m}\frac{[\sinh z_1+\sin z_1-j(\sinh z_1-\sin z_1)]}{\cosh z_1+\cos z_1} \qquad (4)$$

$$\phi=\frac{B_1}{\sqrt{2}m}\frac{[\text{ber } y_1\,\text{bei}'\,y_1-\text{bei } y_1\,\text{ber}'\,y_1-j(\text{ber } y_1\,\text{ber}'\,y_1+\text{bei } y_1\,\text{bei}'\,y_1)]}{\text{ber}^2\,y_1+\text{bei}^2\,y_1} \qquad (5)$$

The equation in Bessel's functions applies of course to the cylinder.

The corresponding average flux densities are

$$B_{ave}=\frac{B_1}{z_1}\frac{[\sinh z_1+\sin z_1-j(\sinh z_1-\sin z_1)]}{\cosh z_1+\cos z_1} \qquad (6)$$

$$B_{ave}=\frac{2B_1}{y_1}\frac{j[\text{ber } y_1\,\text{bei}'\,y_1-\text{bei } y_1\,\text{ber}'\,y_1+\text{bei } y_1\,\text{bei}'\,y_1)]}{\text{ber}^2\,y_1+\text{bei}^2\,y_1} \qquad (7)$$

Equations 6 and 7 may be divided by B_1. Then the absolute value of the right hand sides will be the effective flux penetration as a fraction of half the lamination thickness, or as a fraction of the cylinder area which can be reduced to a radial depth.

Then the right hand side of the equation derived from equation 6 can be multiplied by r_1 to give the effective flux penetration in inches, and this may be divided by 1.4 $(\rho/\mu f)^{1/2}$ to get a factor K which gives the penetration in dimensionless terms. This value used for effective flux penetration in inches into a thick lamination, $1.4(\rho/\mu f)^{1/2}$ is equivalent to the formula for penetration in centimeters, $3.57(\rho/\mu f)^{1/2}$, given by Steinmetz.[3] The net effect of the operations described is to divide the absolute value of the term in hyperbolic and circular functions by $\sqrt{2}$.

By somewhat analogous steps the effective flux penetration into a solid cylinder may be compared to the Steinmetz formula and these comparisons are shown plotted together in Figure 9. For values of $z_1<2$ the skin effect is of little consequence, since penetration is limited by the size of the piece. For $z_1>2$ the penetration into the cylinder is substantially greater than into the lamination.

This difference is due solely to the curvature of the convex cylindrical surface and by an extension of the same idea the penetration into a concave surface would be substantially less than into the plane surface of a lamination.

This reasoning is entirely valid, but it is more satisfactory to approximate the con-

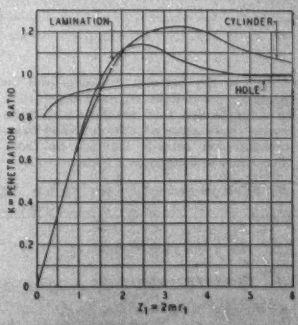


Figure 9. Actual flux penetration into a cylinder or lamination, or radially outward from a round hole in an infinite mass, divided by the Steinmetz formula value and plotted against $z_1(=2mr_1)$. Comparison is based on cylinder diameter = hole diameter = lamination thickness

Size Reduction and Rating Extension of Magnetic Air Circuit Breakers up to 500,000 Kva, 15 Kv

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AIR CIRCUIT BREAKERS rapidly are becoming the standard of the industry for voltages up to 15,000 volts and for kilovolt-ampere ratings of 50,000 to 500,000 kva. Their general desirability as compared to oil-type switchgear is now recognized by most users.

As has been previously pointed out before the Institute, the present trend of air circuit breaker development was started by the introduction in 1929 of a 500,000-kva 15,000-volt circuit breaker based on the multiple cold-cathode principle of Slepian.[1,2] It may be noted that this rating is today, 16 years later, the highest standard rating for self-contained air circuit breakers. The original development was followed by successively producing ratings down to 100,000 kva at 2.5 and 5 kv.

Although large numbers of these multiple cold-cathode-type breakers are still giving excellent service, this principle was found to have certain limitations. Therefore, the magnetic deion principle[3] was developed, and it permitted ratings up to 250,000 kva at 5 kv.

These ratings of magnetic air breakers were smaller and simpler than the previous types of air breakers and created a demand for 7.5- and 15-kv breakers of more compact construction.

The next step in the development of the magnetic air breaker, however, was not a rush to enlarge the interrupters to cover the 7.5- and 15-kv ratings, since these were already covered by other forms of self-contained air breakers. It was instead an earnest attempt through research and development to improve further the interrupting principles so that a breaker of more compact construction and improved characteristics could be offered. These aims have now been fulfilled, and the magnetic air breakers are now available in all ratings up to 15 kv 500,000 kva. The 15-kv 500,000-kva unit, while containing the fundamental features of the original magnetic air breaker as presented to the Institute by Ludwig, Grissinger, and Nau in 1939,[2, 4] has been developed and refined until the interrupting capacity available in a given space has been more than tripled.

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The New Interrupter

It is reasonable to say that if a certain arc chute will interrupt a given voltage, then by doubling the length it will interrupt twice as much voltage. This is generally true on account of momentary current leakage following current zero, giving the effect of a potential divider to equalize voltage over the length of the arc chute. However, consideration shows that increased voltage rating obtained in this way is not economical in floor space. To keep the space requirement within desirable limits, the desirable course of action was to increase the interrupting capacity within a given space.

It was believed that by making a systematic study of all the known factors influencing arc interruption in air, each factor could be emphasized and co-ordinated into an optimum over-all design for a given rating.

From previous experience with the magnetic construction, it was decided that the general idea of multiple arc-resisting plates having V-shaped or tapered slots into which the arc is moved showed the greatest promise of success. The plate type of construction, in general, permits practical manufacture with high grade refractory ceramic material. As is well known, materials of this general class are

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dition at the bottom of the groove by studying the radially outward penetration of magnetic flux from a hole in an infinite mass. It is assumed that a helical magnetizing coil extends through the hole. The solution of equation 1 is then

$$B = B_1(\ker y + j\,\mathrm{kei}\,y)/(\ker y_1 + j\,\mathrm{kei}\,y_1) \quad (8)$$

Since[5]

$$\int_0^y y\ker y\,dy = y\,\mathrm{kei}'\,y \quad \text{and}$$

$$\int_0^y y\,\mathrm{kei}\,y\,dy = -y\ker' y$$

$$\phi = B_1(-\mathrm{kei}'\,y_1 + j\ker' y_1)/\sqrt{2m} \times (\ker y_1 + j\,\mathrm{kei}\,y_1) \quad (9)$$

If we take the absolute values

$$\phi = \frac{B_1}{\sqrt{2m}}\sqrt{\frac{\mathrm{kei}'^2\,y_1 + \ker'^2\,y_1}{\ker^2 y_1 + \mathrm{kei}^2\,y_1}} = \frac{B_1}{\sqrt{2m}}Q \quad (10)$$

If ϕ = depth of penetration in inches, the integrated flux $2\pi r_1\phi$ can be expressed in terms of ϕ and r_1, or in terms of Q and m, so that

$$[(r_1+\phi)^2 - r_1^2]\pi B_1 = 2\pi r_1 B_1 Q/\sqrt{2m} \quad (11)$$

$$\phi = r_1(-1 \pm \sqrt{1+2Q/y_1}) \quad (12)$$

Let ϕ_s = flux penetration in inches according to Steinmetz formula $= 1/\sqrt{2m}$; then

$$K = \phi/\phi_s = y_1(-1 \pm \sqrt{1+2Q/y_1}) \quad (13)$$

The values of K from this equation have been added to Figure 9 to complete the comparison. Values of the ker and kei functions and their first derivatives have been taken from Savidge's[5] table, which seems to be about the only one in existence. The tabular interval of 0.1 makes possible reasonably precise detail for values of y_1 greater than 0.1, corresponding to z_1 greater than 0.14.

It should be understood, of course, that for large values of mr_1, the actual flux penetration in any case approaches that stated by the Steinmetz formula.

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non-gas forming and are chemically stable even when exposed to arc temperatures. They do not take on appreciable moisture from the atmosphere and are high in dielectric strength. By proper choice of composition, high resistance to thermal shock also can be obtained.

The theory of magnetic deionization has been described before the Institute.[4] Briefly, it consists of moving the arc toward the closed tops of slots in insulating arc-resisting plates. At this position the presence of a strong magnetic field imparts to the electrons an upward velocity. They in turn bombard gas particles and produce an actual blast of gas perpendicular to the arc, which action requires the arc continually to ionize fresh gas in considerable quantities. When current zero is reached, this action continues in a sufficient degree effectively to deionize the plurality of short lengths of arc near the edges of the slots.

This theory would indicate that increased interrupting capacity can be obtained by increased strength of the magnetic field. While this is a factor, it was found that blindly increasing the field strength might be detrimental rather than helpful. Slot shape, plate spacing, and magnetic field strength are interdependent and must be co-ordinated for optimum results. The design of the interrupting unit is most easily approached by blending the proper plate structure with a strong magnetic field.

The theory of magnetic deionization points out that interruption depends upon the rate of deionization at the instant of current zero. If some way could be found to control the field so that it would have appreciable strength at current zero, the interrupting capacity apparently should be increased. In other words, if the field flux was made to lag behind the arc current, it would have some magnitude at arc current zero. On the other hand, an in-phase flux is zero when the arc current is zero and positive driving forces are, therefore, momentarily absent. Tests proved that if the field flux lagged the arc current by the proper phase angle, the voltage limit of a well-designed interrupter was increased considerably.

A phase shift between the magnet flux and arc current may be accomplished by shunting the magnet coil with a resistor. It was not possible to predict mathematically the advantage to be gained by a particular phase shift. Therefore, it was necessary to make numerous tests to find the best value. However, the resistor seemed to be an undesirable appendage, and theory indicated that the same result could be accomplished with a shading coil. Such a coil was calculated to supply the same effect as the previously determined best value of resistance, and confirming tests demonstrated that this shading coil gave a correct phase shift. In the final design, the shading coil consists of a single turn around the magnet yoke adjacent to the magnet coil so that in operation it encloses the total flux.

Slot shape and plate spacing also are important factors in the performance of the interrupter, inasmuch as they control the motion of the arc through fluid friction and restriction. Mathematical analysis is helpful in determining the designs, but it is necessary to rely on empirical data on account of unpredictable factors such as gas temperatures, velocities, etc.

The fundamental theory of the magnetic Deion breaker states that interruption is accomplished by the blast of gas perpendicular to an arc held stationary at the ends of slots. This blast deionizes the arc and establishes dielectric strength. In the development of the new interrupter, it was determined that advantage could be taken of the better field and its phase relationship by elongating the arc exposed to this blast. Therefore, the full value of these factors was utilized by offsetting the ends of the slots in the plates.

Referring to Figure 1, one terminal of the magnet coil is connected to the upper stud. The other terminal is connected to the panel-end horn. The coil is introduced into the circuit by the impingement of the arc on the panel-end horn and the interruption of the short length of arc between the horn and the upper stud. The extra field strength which has been introduced to produce a more efficient interrupter gives rise to a new problem. All the flux across the interrupting space must thread the magnet coil. This means that when short-circuit current is introduced into the coil, a reactance voltage of several hundred volts appears across the terminals of the coil. To introduce the short-circuit current into the coil quickly and positively against this reactance voltage requires that an auxiliary or transfer interrupter be built into the arc chute. This interrupter, although very compact, must perform a duty comparable to that of a high-capacity low-voltage breaker.

Figure 1 is an illustration of an arc chute for a 15-kv 500,000-kva circuit breaker based on the above considerations. The magnetic structure for this unit consists of one coil and one magnet. With this type of construction, the magnet shoes form a support for the arc chute which makes possible the quick and easy removal of the relatively light arc chute for inspection while the heavy magnet remains on the breaker. However, more important is the simplification of insulation problems and the energizing of the field simultaneously over the entire interrupting structure so as to obtain fast uniform arc motion.

The contacts are of conventional design. In an opening operation, the current is transferred from the main current-carrying contacts to secondary contacts and then to the arcing contacts, which are protected by inlays of silver-tungsten alloy. When the arcing contacts part, the current loop in the contact structure causes the arc to expand into the arcing chamber. Suitably placed iron draws the arc into the transfer stack, which interrupts the section of arc between the stationary arcing contact and the panel-end arc horn. The current path is now from the top bushing stud through the magnet coil, into the adjacent arc horn, through the arc in the main interrupting stack, and into the opposite arc horn which is connected to the opposite side of the cir-

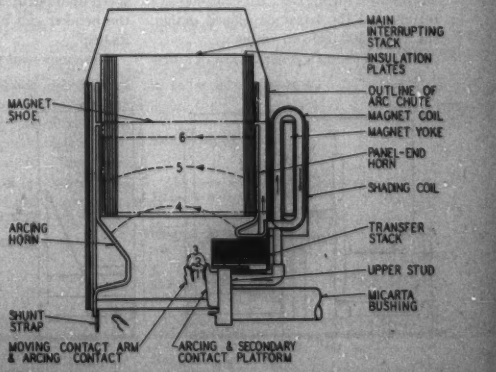

Figure 1. Schematic illustration of a 500,000 kva 15-kv magnetic interrupter

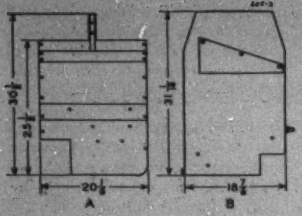

Figure 2. Progress in magnetic interrupter design

A—A 100,000-kva 5-kv arc chute of early design
B—The new 500,000-kva 15-kv arc chute
Both have ceramic interrupting plates of the same width

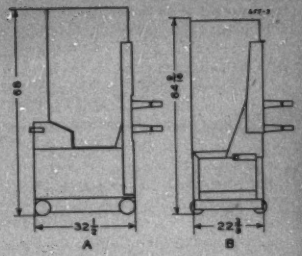

Figure 3. Progress in magnetic air breaker design

A—An early 5-kv 150,000-kva unit
B—The current design
Note smaller depthwise dimensions of the later design. Both units are for 26-inch metal-clad cell width

Figure 5. General view of the new 15-kv 500,000-kva magnetic air breaker for metal-clad horizontal drawout switchgear

cuit. The field is now energized, and interruption takes place at the next current zero.

The proper amount of phase shift between the current and the field is obtained by using a carefully designed shading coil placed around the magnet core adjacent to the coil. This shading coil also eases the duty on the transfer stack by slowing the rate of rise of restored voltage across it when the transfer arc is extinguished.

Figures 2, 3, and 4 illustrate some of the results accomplished by this development. Figure 2 is an outline comparing the 5-kv 100,000-kva arc chute of an earlier design with the new 15-kv 500,000-kva arc chute. Both use ceramic plates of the same width. Figure 3A shows the outline dimensions of the original magnetic air breaker for 5 kv and 150,000 kva, while 3B shows the current design for the same rating, which is also applicable at 2,300 volts. It will be noted that the later design saves considerable depth of floor space. Figures 4A, B, and C show the relative size of the original 5-kv 150,000-kva rating, the 7.5-kv 250,000-kva rating, and the latest developed design, the 15-kv 500,000-kva rating.

Figure 5 shows a general view of a new 15-kv breaker. In line with the present general trend, this unit is designed particularly for metal-clad switchgear and as shown constitutes the complete removable element. In this view it will be noted that the horizontal drawout construction results in an inherently transportable removable unit with self-contained secondary and ground contacts. This permits quick movement to the test position and quick reconnection of control circuits for testing within the cell. It also permits quick interchange of breakers in a cell. The location of the main barrier, arc chute, and contacts also permits easy removal and inspection of those parts.

The arc chute is placed above the contacts, which is the most natural position for it because this position permits the arc to be drawn horizontally and moved vertically upward. With this construction, thermal convection assists in moving low current arcs into the interrupters. An auxiliary air piston may be added to speed up interruption of low currents, but the breaker can interrupt them without its help.

The component parts of the breaker are arranged so that the arc chute compartment can be vented directly to the outside atmosphere, thus completely isolating this compartment from the bus structure. The 19-inch-long arc chute for a 15-kv 500,000-kva breaker is admirably suited for this drawout construction and adds further to its inherent advantages in the economy of floor space required.

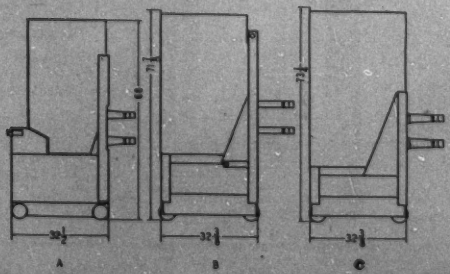

Figure 4. Progress in 15-kv magnetic air breaker

A—The 5-kv 150,000-kva breaker of early design
B—A 7.5-kv 250,000-kva breaker
C—The new 15-kv 500,000-kva magnetic breaker

Tests on the Breakers

In line with present practice, it is almost needless to say that many full power interrupting tests were made in developing the new ratings. These tests again have demonstrated the ability of the ceramic arc chute to withstand repeated interruptions with low deterioration.

The breaker was connected across the terminals of a 60,000-kva star-connected high power laboratory generator, and the short circuit was formed by a copper bar bolted across the load side of the breaker. The generator neutral was grounded through a 7-ohm resistance, while the short-circuiting bar was ungrounded, which is equivalent to a grounded fault on an ungrounded system. Currents were limited by air core reactors.

Typical oscillograms are shown in Figures 6 to 9. Figure 6 shows a 3-phase interruption at 505,000 kva and 13.2 kv. Figure 7 shows an interruption at 163,000 kva and 13.2 kv. Figure 8 is of interest in that it shows a single phase interrup-

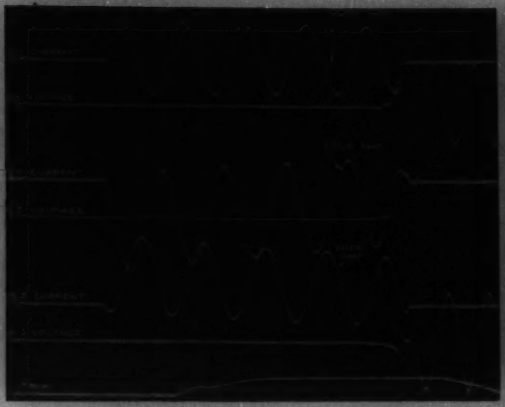

Figure 6. Oscillogram of 3-phase ungrounded short-circuit interrupting test on 15-kv 500,000-kva magnetic air breaker shown in Figure 5

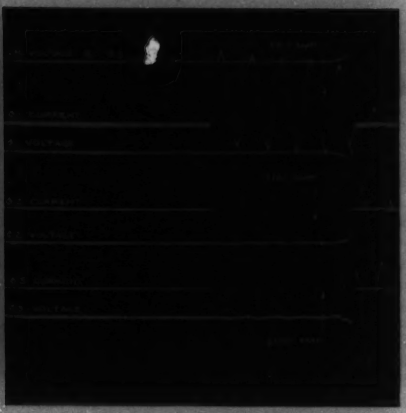

Figure 7. Oscillogram of 3-phase ungrounded fault at 163,000 kva on the 500,000-kva breaker

tion of 7,300 amperes at 13.2 kv across a single pole.

Figure 9 illustrates, by single phase oscillograms, an interesting characteristic of the new types of magnetic interrupters. On all tests except those at very low currents, when the field is energized 30 degrees or more ahead of a current zero, the breaker will interrupt on that zero. On the other hand, the current is not likely to transfer to the coil on the rising part of the current wave, and the arc will remain in the comparatively wide arc box at low arc voltage until the current has gone through its peak value. Coil transfer is then completed, and the strong field drives the arc up to the ends of the slots at extremely high velocity. At the ends of the slots, deionization and interruption is accomplished. As shown in Figure 9A, this type of interruption, with high arc energy released during only a small portion of the half cycle, is characteristic of an interrupter of this type. This produces a minimum of heating and deterioration in the arc chute. As shown in Figure 9B, another type of interruption is possible, and that is where the field is energized fewer than 30 degrees before current zero. On a probability basis, this type of interruption should occur in one out of six interruptions. Insufficient time is available to drive the arc to the top of the slots before current zero, and the arc must remain there for another half cycle. However, the high degree of restriction and the loss of ions from the arc stream on account of the field keep the arc resistance so high that the current reaches only a small magnitude. The arc energy released is not much greater than in the previously described type of interruption. Throughout all the tests made in this development, it was impossible to find any difference in interrupting capacity between the two types of interruptions.

Figure 8. Oscillogram of single-phase interruption at 13.2-kv on single pole of the 15-kv magnetic breaker

Figure 9. Oscillograms illustrating two types of interruption on the new magnetic breaker for 15 kv (see text)

The tests described and the oscillograms shown apply to the 500,000-kva 15-kv breaker. The same principle of interruption has been applied to breakers of other ratings, namely, 150,000 kva and 250,000 kva at 15 kv, and similar test results have been obtained. The same principle of interruption has been found to work equally as well on the currents encountered at 7,500 volts, including 500,000 kva at 6,600 volts and 25 cycles.

Conclusion

The principle of magnetic deionization has been extended to air circuit breakers of the 15-kv class with interrupting ratings up to 500,000 kva. The interrupter has been so refined and improved that the increase in kilovolt-amperes rating of up to 500 per cent has not resulted in undue increase in space requirements. The short arc chute, 19 inches long for a 500,000 kva 15 kv unit, has made possible compact horizontal drawout construction with all its inherent advantages.

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A New Line of High-Voltage Outdoor Tank-Type Oil Circuit Breakers

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THE TREND of the past few years and studies of future trends indicate an oncoming demand for higher interrupting capacities and decreased interrupting and reclosing times. Today there may be relatively few applications which justify these more severe requirements, but there is every indication that as time passes they will become more and more universal.

A year ago there was described before the Institute[1] a development in tank-type breakers which made possible interruption of short-circuits up to 3,500 megavolt-amperes within three cycles in the voltage range from 115 kv to 161 kv with 20-cycle reclosing. Field tests were also reported[2] substantiating this performance. The present paper describes further developments in these breakers, resulting in reduced over-all dimensions and increased convenience in handling, while maintaining or improving the desirable performance characteristics. These characteristics have also been realized in an interrupter and breaker suitable for operation at 230 kv.

Figure 1 shows the 138-kv breaker.

From both structural and functional standpoints, a discussion of these breakers divides itself naturally into four major parts:

1. The interrupter.
2. The bushing.
3. The tank and top frame.
4. The operating mechanism.

In order to meet the exacting performance requirements of high interrupting capacity, fast interruption, and rapid reclosure, and at the same time to reduce maintenance to a minimum and readily make accessible those parts which require inspection and maintenance, each one of these parts must receive careful attention from the designer. This development has involved significant improvements in all of them. These changes will be discussed under the four corresponding headings.

The Interrupter

As the interrupter is the part primarily responsible for the performance of the distinctive function of the circuit breaker, it is natural that this should receive first consideration.

A cross-sectional view of the interrupter of the earlier breaker is shown in Figure 2, and a similar view of the new interrupter is shown in Figure 3. Figure 4 shows the new interrupter with separate views of the moving system and the resistor. Figure 5 shows two interrupters mounted on bushings with blade, lift rod, and guide in place as when assembled in the tank.

The same general principle of interruption is used in both designs. Interruption is performed by a number of 2-break units, each of which consists of one break whose primary purpose is to generate pressure and a second break so located that the arc drawn there is placed in the path of a blast of oil forced out through properly located ports by the pressure generated by the first arc. For application at voltages from 115 kv to 161 kv, two such units are used in each interrupter. Thus, starting at the lower end, current enters the interrupter on the lower stationary contact, passes through the elkonite contact tips to the bridging contact, and flows from the other end of the bridging contact to the lower end of the intermediate stationary contact. This cycle is repeated in passing from the upper end of the intermediate stationary contact to the upper stationary contact. This path includes four breaks, of which those at the lower stationary contact and the upper end of the intermediate contact are located away from ports and serve principally the function of pressure generation. The other two breaks are immediately adjacent to ports, and the arc there is interrupted by the blast of oil flowing out through the ports.

An appreciable reduction in the arcing time of the new interrupter has been achieved by strengthening the opening springs on the interrupter to increase the speed of its moving parts. The tendency to increased pressure associated with this change in speed was more than counterbalanced by lengthening the arcing plates and by using the pressure control ports shown in Figure 3.

The arcing plates function by shortening the pressure generating arc.

The pressure control ports are located near the pressure-generating arc, but far enough away to be reached by the gas bubble only when interrupting high currents. Their use was suggested by the observation that in operations in which a gas bubble might be expected to be present in the interrupter, as in the second interruption of a reclosing operation, the pressures experienced were found to be much lower than when such a bubble was not present. Thus it appeared desirable to provide the cushioning effect of such a bubble for all conditions, and as the high pressures appeared only towards the end of the arcing period, the most convenient way to accomplish this was to allow the lighter pressure in the early part of the arcing period to force oil out through these ports and thus create additional expansion space for the bubbles already present at the contacts.

The effectiveness of this combination in achieving both short arc lengths and low pressures is evident from Figures 6 and 7, in which arc duration and interrupter pressure, respectively, are plotted against current interrupted for both the

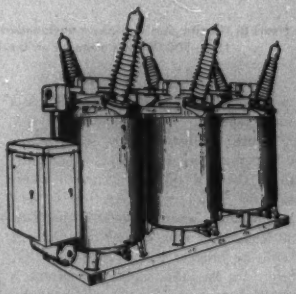

Figure 1. The new 138-kv oil-blast circuit breaker, 3,500-megavolt-ampere interrupting rating, 3-cycle interrupting time rating and 20-cycle reclosing time rating

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The authors wish to express their indebtedness to many of their associates who materially assisted in the development of these breakers. In particular, T. R. Coggeshall and J. M. Milne have contributed ideas for the solution of the many problems involved and have been untiring in following the innumerable details which are an indispensable part of such a program.

new and the superseded interrupter. It will be noted readily that the circled points, representing the new interrupter, show a substantial improvement in both respects, with satisfactory performance at currents well beyond that corresponding to the 3,500-megavolt-ampere standard rating.

The simplification of the present design is obvious from a comparison of Figures 2 and 3. The principal changes are as follows:

1. The ends of the interrupters are secured to the cylindrical herkolite walls by means of metal studs. This has been found to be quite as strong as the earlier construction and results in a very appreciable reduction in the diameter of conducting material. There is also a substantial reduction in weight, which is accentuated by the use of a light alloy for the end pieces.

2. The moving contact assembly has been simplified greatly by placing all of the contact springing immediately below the bridging contacts themselves, thus eliminating the necessity for any additional cushioning springs at the bottom of the interrupter. This has made possible the use of a simple textolite cylinder, which makes an excellent guide bearing, at the point where the moving part passes through the bottom plate of the interrupter. A strong opening spring and a buffer spring are placed around this cylinder, the one insuring that the moving parts of the interrupter move with the breaker crosshead to the limit of the interrupter stroke and the other controlling overtravel of the contacts on the closing stroke.

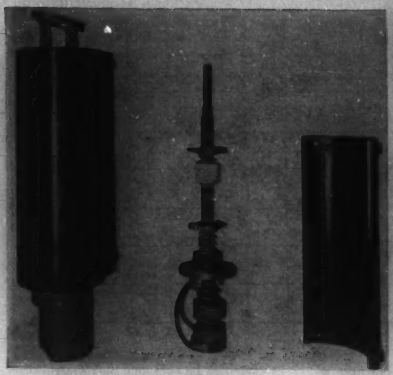


Figure 4. The 115-kv–161-kv interrupter with additional views of the moving part assembly and the resistor

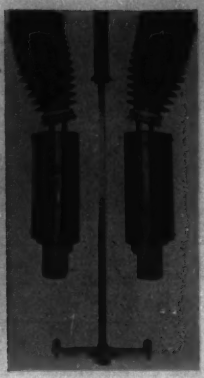


Figure 5. Pole unit assembly of interrupters for the 138-kv breaker

3. Both the new and the superseded interrupter use a parallel resistor for positive control of overvoltages in connection with the interruption of line-charging currents.[3] The new resistor is shown at the right-hand side of Figure 4. It consists of a helix of nichrome wire which is wound on a grooved board that has its short dimension molded into the shape of a circle arc. Protective covers are secured to the board. The resulting assembly conforms to the outside of the interrupting cylinder and thus requires less space than the older resistor.

4. Additional items that will be helpful in facilitating inspection and maintenance are the smaller electrostatic shield at the bottom of the interrupter and the elimination of the upper insulating shield, both made possible by removal of the clamping metal outside the interrupting cylinder.

The interrupter of Figures 3 and 4 is used at voltages from 115 kv to 161 kv. For application at 230 kv, the interrupter shown in Figure 8 is used. This is quite similar in principle to the lower-voltage interrupter but has three pairs of internal

Figure 2. Cutaway view of 115-kv–161-kv interrupter of the superseded design

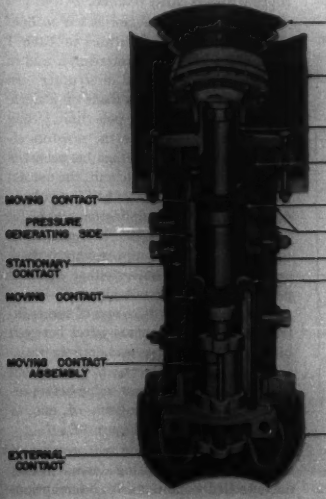
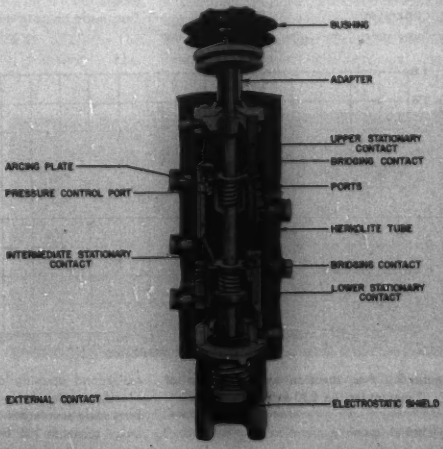


Figure 3. Cutaway view of 115-kv–161-kv interrupter of the new design



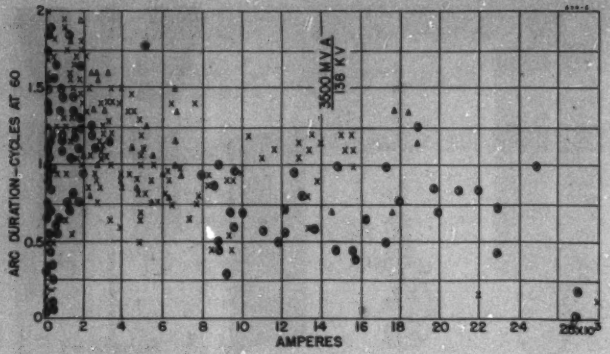


Figure 6. Arc duration as a function of current for 115-kv–161-kv interrupters

X—Superseded interrupter, initial opening operation

Δ—Superseded interrupter, second opening operation on reclosing duty cycle

The same symbols enclosed in circles represent the new interrupter under the same conditions

Tests made on a pole unit at voltages from 14.5 kv to 132 kv

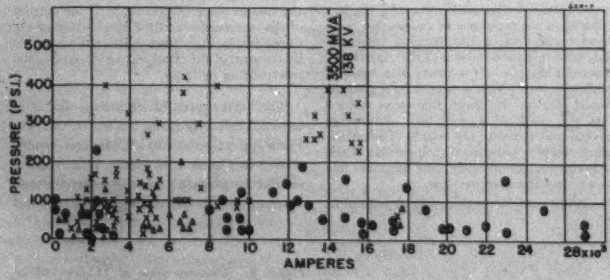


Figure 7. Interrupter pressure as a function of current for 115-kv–161-kv interrupters

X—Superseded interrupter, initial opening operation

Δ—Superseded interrupter, second opening operation on reclosing duty cycle

The same symbols enclosed in circles represent the new interrupter under the same conditions

Tests made on pole unit at voltages from 14.5 kv to 132 kv

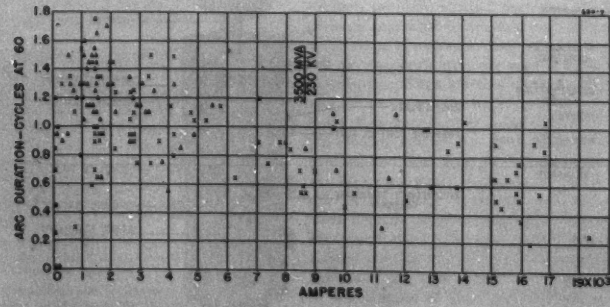


Figure 9. Arc duration as a function of current for the 230-kv interrupter

X—Initial opening operation

Δ—Second opening operation on reclosing duty cycle

Tests made at voltages of from 8.4 kv per interrupter to 132 kv per interrupter

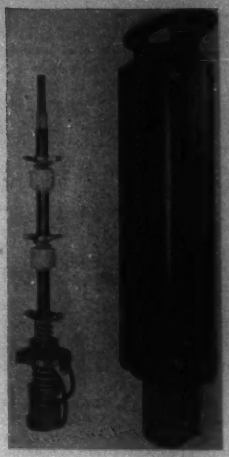


Figure 8. The 230-kv interrupter

breaks instead of two. Also, the resistor has somewhat more thermal capacity as required at the higher voltage. The interrupting performance of this interrupter is shown in Figure 9. It will be noted that the arcing time varies from less than 1/2 cycle to $1^1/_2$ cycles at currents above 25 per cent of rating. With a contact-parting time of $1^1/_2$ cycles, this gives a breaker-interrupting time of from two to three cycles, or with the conventional tripping arrangement, a 5-cycle interrupting time is easily realized.

The interrupting performance on line-charging currents is indicated in Table I for the 115-kv–161-kv interrupter and in Table II for the 230-kv interrupter. In each case the tests were made on a single interrupter or half a pole unit, using static capacitors. Since the resistors effectively divide the voltage between the two interrupters of a pole unit, the normal voltage for such a test is half leg voltage or 46 kv for 161-kv application and 66 kv for 230-kv application. In both cases, tests were made at approximately these voltages and also at a voltage from 20 per cent to 33 per cent higher to insure adequate margin to take care of surges introduced by any mutual effect between phases. Performance was entirely satisfactory in all tests, the voltage being limited to twice the crest value before interruption. An oscillogram of one of these tests is shown in Figure 10.

A comment is in order with respect to short-circuit interrupting tests. Under uncontrolled conditions of interruption,

there are two elements subject to rather wide variation. These are:

1. The point on the voltage wave at which the short circuit is initiated.

2. The point on the current wave at which the breaker is tripped.

With the reduction in arcing time that has taken place in recent years, the influence of these variations becomes accentuated to the point where they may be responsible for the difference between four-tenths of a cycle and a complete cycle in arc duration, with a very pronounced difference in interrupter pressure, jar, contact burning, and any other manifestation of severity of duty. To be sure of covering the worst conditions at any voltage and reactance tap, therefore, either a large number of tests must be taken or some control must be exercised over the timing. For over ten years now, the authors and their associates have made extensive use of a special fast-closing breaker with synchronous control to make possible the selection of the point on the voltage wave at which the circuit is closed, and more recently the same type of control has been applied to the tripping of the test breaker. Thus it is now possible to control both the displacement of the short-circuit current wave and the point on the wave at which the contacts separate. It has been the practice first to make exploratory tests over the complete range of variation of these controls and then to concentrate for a number of tests on that condition which appears to be worst. Thus any other random phenomena will have an opportunity to show up at their worst also, and in a reasonably small number of laboratory tests, conditions may be explored which would not appear in many times the corresponding number of field operations or uncontrolled laboratory tests.

Table I. Performance of 115–161-Kv Interrupter on Line-Charging Currents
Tests on One Interrupter

Test No.	Voltage, Kv	Equivalent Miles of Line	Current, Amperes	Arc Duration, Cycles
1	44	190	110	0.3
2	44	190	110	0.3
3	44	190	110	0.0
4	44	190	110	0.1
5	44	190	110	0.1
6	55	190	140	0.1
7	55	190	140	1.6
8	55	190	140	1.6
9	55	190	140	0.0
10	55	190	140	1.4

Table II. Performance of 230-Kv Interrupter on Line-Charging Currents
Tests on One Interrupter

Test No.	Voltage, Kv	Equivalent Miles of Line	Current, Amperes	Arc Duration, Cycles
1	66	190	140	0.7
2	66	190	140	0.2
3	66	190	140	0.7
4	66	190	140	1.0
5	66	190	140	0.9
6	88	110	110	0.9
7	88	110	110	1.2
8	88	110	110	1.1
9	88	110	110	0.9
10	88	110	110	0.6

Bushings

Oil filled bushings for high-voltage oil circuit breakers have an enviable record of performance. While the electrical and mechanical performance of these bushings has been generally satisfactory, numerous improvements have been made for the purpose of reducing maintenance. The sump washer-drain, bell-mouthed breather, amber gauge glass, and thermal seal are the most noteworthy. In recent years it has become obvious that the next step is complete sealing of the bushing against the atmosphere so as to eliminate completely any source of contamination of the filler oil. Numerous designs of sealed bushings have been developed, with the moderate voltage type *L* bushing as one of the first. The experience with over 80,000 of these bushings and varied special applications of sealed oil-filled bushings gave the proper background for developing the completely sealed bushings for the 115–161-kv ratings.

The completely sealed bushing, Figures 11 and 12, uses a general arrangement of insulation similar to that of the original oil-filled bushings, although a number of structural improvements were found desirable. The insulated conductor is surrounded by concentric insulating cylinders of treated paper of high dielectric strength spaced apart so as to give alternate layers of solid insulation and oil. These cylinders are between the live conductor and the grounded support sleeve. Electrostatic shielding is incorporated internally in these cylinders by coating a part of the paper with conducting resin as it is wound. This imbedding of the conducting shield within the cylinder is a distinct improvement over the older method of winding conducting foil on the outside of the cylinders.

Center clamping is used to clamp the bushing parts firmly together. This makes use of the center conductor as a means of clamping the lower porcelain, ground sleeve, upper porcelain, and expansion chamber into an integral unit. Adequate clamping pressure is maintained on the four gasketed joints even with slight differences caused by thermal expansion, by means of short heavy compression springs between the terminal cap fastened to the conductor and the top of the expansion chamber.

Synthetic rubber gaskets impervious to both oil and water are used at all joints. These are confined in appropriate recesses in the metal parts.

Standard circuit breaker or transformer oil is used as a filling liquid. Expansion space for this medium is present in the metal expansion chamber at the top of the bushing. The oil level is registered by a magnetic-type oil gauge incorporated in the expansion chamber and easily visible from the ground, as shown in Figure 13.

The use of center clamping results in a reduction in diameter dimensions because of the omission of the cemented-on clamping rings. This is particularly advantageous at the lower end because it permits smaller current transformers and sim-

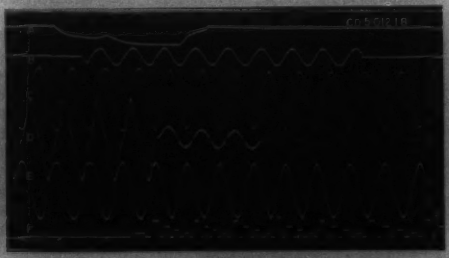


Figure 10. Oscillogram of line-charging current interruption on 115-kv–161-kv interrupter, interrupting 140 amperes at 55 kv across a single interrupter

A—Trip coil current
B—Cathode ray oscillograph control
C—Supply voltage at breaker
D—Current through breaker, showing initial capacitance current, resistor current, and final interruption
E—Alternator voltage
F—Breaker travel: one-half inch per impulse

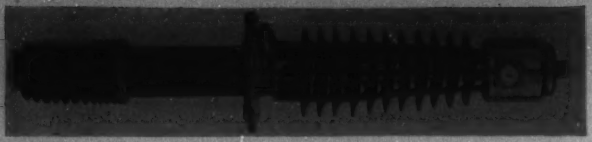
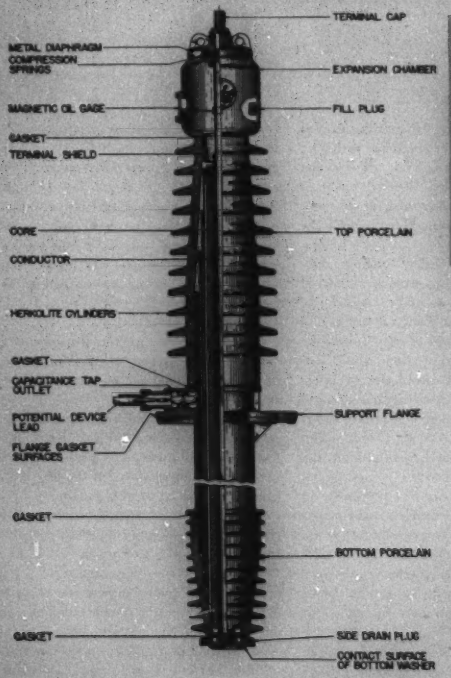


Figure 11. 115-kv sealed oil-filled circuit breaker bushing with capacitance tap having smaller dimensions resulting from center clamping and removal of cemented-on clamping rings



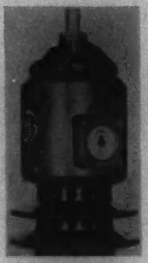


Figure 13 (above). Top of sealed oil-filled circuit breaker bushing showing expansion chamber and magnetic type oil level indicator

Figure 12 (left). 115-kv sealed oil-filled circuit breaker bushing in cutaway semisection showing arrangement of porcelains and gaskets

plifications in the breaker top frame construction.

Exhaustive tests have been made, not only under static conditions but also under operating conditions such as the loadings that bushings are subjected to during the interruption of heavy short circuits. Every attempt has been made to find failure points under both of these conditions. The interrupting tests unquestionably subjected the bushing to the most severe mechanical loadings. On all tests the bushings gave a remarkably satisfactory performance. Many readers will be interested in a performance comparison between the new and the superseded designs. The new design has turned out to be both electrically and mechanically stronger than the older oil-filled type.

An additional feature of the new bushing is the interchangeability with the old design. A long background of interchangeable breaker bushings dictated that from a user's standpoint, the new bushing fall into the same pattern. Therefore, the mounting bolts and flange gasket locations are identical with those of the older bushings. The elimination of the lower clamping ring has permitted shortening of the bushings by about three inches. For replacements, however, a suitable spacer can be provided to compensate for this shortening, and the new bushing is available as a replacement unit for any oil-filled bushing on older oil circuit breakers.

Table III. Comparison of New and Old Designs Illustrating the Substantial Reduction in Oil Requirements and Loading on Foundations

Breaker Rating	Type New	Type Old
115 Kv		
Tank diam., in.	54	54
Weight, lb	36,600	39,400
Oil, gal	2,300	3,420
138 Kv		
Tank diam, In.	54	60
Weight, lb	38,500	47,800
Oil, gal	2,400	2,970
161 Kv		
Tank diam., in.	60	72
Weight, lb	44,800	64,300
Oil, gal	2,950	4,700
230—196 Kv		
Tank diam, in.	78	108
Weight, lb	85,000	168,500
Oil, gal	7,250	14,000
230 Kv		
Tank diam, in.	84	108
Weight, lb	110,000	180,000
Oil, gal	8,800	15,400

Tank and Top Frame

The pole units of the new breakers have a number of design features resulting from changes in the essential component parts (Figure 14). The smaller-sized interrupters made a reduction in tank dimensions possible. The new sealed bushings with smaller lower end dimensions permitted smaller bushing current transformers and a simplified arrangement of the transformer housing. The increasing demand for more 3-cycle breakers made it advisable to design the pole unit linkage with this objective in mind. Many of the accessories were simplified and relocated to facilitate maintenance.

The smaller size and smooth contours of the new interrupters have permitted substantial reductions in the sizes of the 138-, 161-, and 230-kv breakers and at the same time have improved their overvoltage performance. Table III shows a comparison of the new practice and the old.

The changes in the bushing current transformer housings resulting from the smaller bushings are quite striking as compared with superseded designs. As shown in Figures 1 and 14, the smaller housing fits within the dome outline so that space is available for two current transformers per bushing without a special design. The conduit connections are large enough for the leads of two current transformers so that a second set can be easily installed in the field. The new arrangement also makes it possible to remove the current transformers over the lower end of the bushings. Thus changes can be made without the laborious pro-

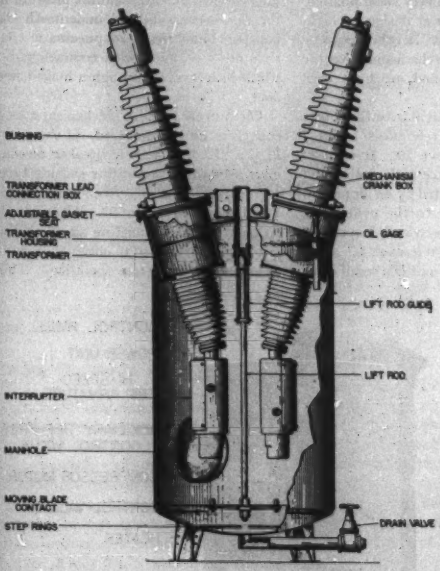


Figure 14. Cross-section of pole unit showing relationship of component parts: interrupters, bushings, tank structure, and bushing current transformers

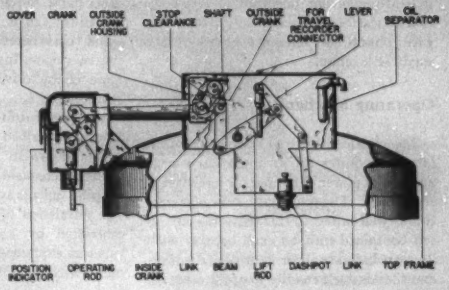


Figure 15. Pole unit breaker mechanism showing straight line linkage and crank housing above operating mechanism

cedure of removing the bushings. The new current transformers have all of the characteristics prescribed by various breaker standards. The current transformers are treated to provide a positive protection against water absorption. The tops of the transformer housings which support the bushings have a special gasket arrangement to permit tilting of the bushing to obtain proper contact alignment.

The increasing demand for 3-cycle breakers has indicated that the mechanical design should be basically suited to such performance. After several arrangements had been reviewed, it was decided to adhere in general to the straight line linkage which has been used successfully in breakers of this type for the past 20 years. But as shown in Figure 15, its size was greatly reduced by taking advantage of the relatively short breaker operating strokes which have resulted from a proper analysis of the clearing distances needed. A feature of this design is the use of low friction bearings which are particularly helpful where high-speed tripping is required. Gas- and oil-tight seals are provided on the main operating shafts by means of close-fitting bearings with splined shafts and cranks for ready assembly. An external indication is provided in the side crank box housing for determining the proper closed position of the linkage. Self-contained oil-filled dashpots absorb the energy of the moving parts at the end of the opening stroke, and their adjustment has been greatly facilitated by providing a threaded assembly with a suitable locking arrangement.

Operating springs are kept to a minimum. Lightweight moving contacts and pneumatic operation make it unnecessary to provide balancing springs for closing to offset the dead weight of the moving members. Buffer springs to limit overtravel are not required, since this function is incorporated in the interrupter contact springs. Opening springs on the rear pole unit keep the interphase connecting pipes in tension for both closing and opening and can be adjusted readily from outside of the breaker to obtain the proper opening speed characteristics.

Tank supports are used to hold the pole unit tanks above the foundation, so that complete drainage can be obtained without any enclosure which would restrict inspection and maintenance of the underside of the tank, as shown in Figure 16. This arrangement permits a reduction of the size of foundation pads. Side manhole openings as shown in Figure 17 give convenient accessibility, and parts for installation in the tanks are easily transferred. The heavy steel manhole covers are supported by hinged joints. Step rings on the outside of the top frame and on the inside of the tank bottom give a firm footing in spite of adverse weather conditions or the presence of an oil film. The oil level is shown by a float-type gauge whose sight glass is easily visible from the ground. Each pole unit has an emergency vent (Figure 18) built into the top frame for protection against permanent damage to the unit when through some unusual circumstances, excessive tank pressure is present. This has a flat copper diaphragm which is designed to rupture at a pressure much less than the tank strength. A semaphore indicator at the front end of the breaker shows the position of the moving contacts at all times. The front crank box cover can be removed for making adjustments at the upper end of the operating rod. The bottom of each pole unit tank is marked to

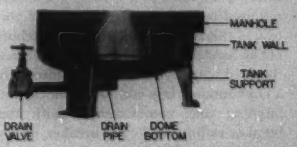


Figure 16. View showing tank supports which give maximum accessibility for maintenance under tank bottom

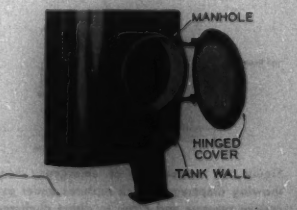


Figure 17. Maintenance manhole in side of tank provides easy access

indicate quadrant positions so that location on the foundation is facilitated. Likewise, plumb bob reference points can be used for leveling.

Operating Mechanism

The modern high-voltage oil circuit breaker requires for its operation a large amount of power delivered for a relatively short time. The pneumatic type of operation is well suited to this requirement. A self-contained unit on each breaker with its own individual air compressor equipment lends itself readily to application on various ratings of breakers whether they are new or in the process of modernization. The breaker pole unit tank is provided with mounting brackets for the support of the housing and its equipment as shown in Figure 19. Electrical connections are no different from those of other types of electrically operated mechanism. Power requirements are very light, and standard control cables will meet all requirements.

Reclosing times are constantly becoming shorter, and the basic design of the pneumatic operation should be adapted to this requirement. The pneumatically trip-free mechanism is so adapted. It is not handicapped by the relatching time of mechanically trip-free designs or any complicated arrangement to avoid it. With the pneumatically trip-free mechanism, the reclosing time is a matter of the size of the power unit and the operating pressure. It is relatively simple to provide for the minimum reclosing times without special designs.

One of the elements involved in the interrupting time of a breaker is the time required to part contacts. A goodly portion of this is dependent on the unlatching of the mechanism after the trip impulse is received. A 5-cycle breaker requires only a conventional trip coil to obtain the unlatching time commensurate with this breaker rating. A 3-cycle breaker, on the other hand, requires a very short unlatching time, and a special design of high-speed trip is necessary. In other respects, the two operating mechanisms have the same characteristics and are built with common parts.

The power unit is similar to those previously described in references 1 and 4 and is shown in Figure 20. It consists of the mechanism frame with closing and tripping linkage actuated by an air piston. The admission of air to the cylinder is controlled by an electrically operated valve as explained in reference 4. Associated with the power unit is a small compressor unit which maintains pressure in the air receiver located underneath the housing. Electrical and pneumatic controls are assembled on a common panel which is accessible through a hinged side door.

The 5-cycle breaker mechanism uses a conventional trip solenoid, as shown in Figure 21. The 3-cycle breaker mechanism uses a high-speed flux-shifting type trip similar to that described in Reference 1 and shown in Figure 22. An auxiliary air control valve admitting air above the piston also is required to obtain the equivalent time on a trip-free operation. This

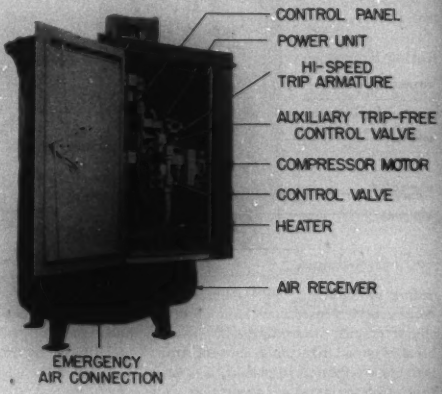


Figure 19. A pneumatic operating mechanism for a 3-cycle, 20 - cycle - reclosing 115-161-kv breaker

The complete unit is mounted on the first pole unit tank

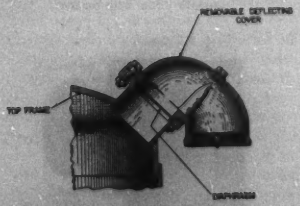


Figure 18. Assembly of emergency vent showing diaphragm which ruptures under excessive pressure and cover to direct discharge to ground

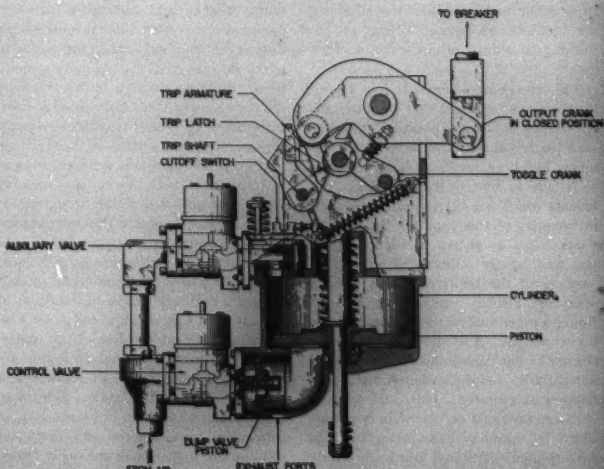


Figure 20. Cross-section of a 3-cycle pneumatic operating mechanism showing the power unit with air control valve and closing and tripping linkages

Figure 21. Trip arrangement for a 5-cycle breaker showing parts on frame for adapting high-speed 3-cycle trip

Figure 22. Trip arrangement for a 3-cycle breaker showing flux-shifting trip for high-speed operation

is assembled directly above the main control valve.

Rating Standards

A careful examination and analysis of the breakers described in this paper indicates that there is very little about them that reasonably can be changed in order to produce a breaker with lower interrupting capacity and lower cost but otherwise meeting the high standard of performance of the breaker as described. This suggests the use of only one breaker design and one rating for each voltage. This would reduce the number of ratings listed in the present American Standards Association standards for 115- to 230-kv breakers from 13 to 4. The resulting simplifications eventually would be of benefit to both user and manufacturer.

Conclusions

This paper has described a line of outdoor tank type oil circuit breakers with voltage ratings from 115 kv to 230 kv and capable of handling all standard interrupting ratings at these voltages with liberal margins on a 20-cycle reclosing basis. The breakers can be adapted to either 3-cycle or 5-cycle operation.

These breakers incorporate improved performance, smaller dimensions, and lower weight both of the breaker as a whole and of many of the parts which require handling in inspection and maintenance.

The authors recommend consideration of the reduction of the number of standard breaker ratings in the 115-kv–230-kv voltage range to one rating for each voltage.

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Shoran Precision Radar

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Synopsis: Shoran navigational radar is generally credited with being the most precise system of its type devised by man. The history of the conception and development of the principles employed, as well as a description of the physical make-up of the equipment, are of interest. Recent military declassification permits the exposition of both as set forth in this paper.

SHORAN is the common name for Army radar sets AN/APN-3 and AN/CPN-2. The equipment is used for high-precision position-finding in aerial navigation, principally for blind bombing and aerial mapping, although several other practical applications have been suggested. The term Shoran is a contraction of the two words short and range. What might at first appear to be a slightly derogatory title—in view of satisfactory performance out to 250 miles—has a logical explanation in the sequence of events prior to adoption of Shoran as the semiofficial designation. The history of the conception and development of the equipment pre-dates that of Loran, the widely used and now well-known long range navigational system. Development work on the latter was also carried on in RCA Laboratories under contract to the Office of Scientific Research and Development after its original inception by the Radiation Laboratory of the National Defense Research Committee. The Loran range of operation was approximately three times that of Shoran. Thus, while work progressed simultaneously on both in the same laboratory after April of 1942, Loran was the first to be adopted, named, and put into general use by the armed services, and the term Shoran for the shorter-range, higher-precision device followed almost automatically. Actually the two are completely dissimilar in equipment and operation. The only common aspect lies in the fact that each is used for aerial navigation.

History of the Shoran Development

The history of the development of Shoran is the story of a search for extreme accuracy of propagation time measurement coupled with ruggedness and reliability of equipment and simplicity of operation. It can truthfully be said that all of those aims were accomplished without compromising any one of them for another.

So much has transpired since the start of war developments that it is difficult to transport one's thoughts back seven years to the fall of 1938. At that time, war in Europe seemed a possibility but was still a year away. The concept of pulsed transmitters of radiant energy for the purpose of propagation time and distance determinations was not widespread. The term radar was nonexistent, and the only generally conceived applications of radio to war needs were for communication purposes or possible remote control of guided missiles of one sort or another.

At that time, work on television transmission and reception equipment was proceeding in many laboratories throughout the world. One of the knotty problems which vexed every television receiver engineer was that of multipath or "ghost" images which so often marred his otherwise creditable results. The television pictures in the industry service division of RCA Laboratories were no exception. The signals received at 711 Fifth Avenue in New York, N. Y., from the Empire State Building often showed as many as five separate and distinct ghost images when inside (or poorly exposed outside) antennas were used. Analysis of the picture content with particular reference to the horizontal displacement of a particular ghost image and the ratio of that displacement to the length of a complete scanning line gave a good indication of the increased path length of the reflected signal which caused the ghost.

At that time the Radio Manufacturers Association television standards specified a 441-line television picture, of which approximately 400 lines were visible, the other ten per cent being used for the vertical synchronizing action.

The aspect ratio of the pictures was four horizontal to three vertical. Thus, there were approximately 530 picture elements along each line. The time required for the scan of the visible portion of each line was 64 microseconds, and since a ghost image displaced by two picture elements was plainly discernible, it was evident that a reflected signal which arrived as much as one fourth microsecond later than the direct signal was detectable. Such a ghost would be displaced approximately 1/32 of an inch on a 12-inch tube picture, and reference to the velocity of propagation indicated that it had traveled about 250 feet farther than the direct wave. The position of multipath images displaced by as much as one fourth inch or more could often be measured to the nearest 1/64 of an inch, and thus the extra distance traveled could be determined to within ±125 feet.

These findings gave rise to the belief that specially designed equipment built primarily for the purpose of path length determination could give an accuracy of ±50 feet or better, and the considerable thought given to that possibility in the fall of 1938 resulted in the early concept of Shoran as it is today.

Actually it was not known, at first, to what uses a system for accurate transmission path length measurement could be put, but it seemed logical one use might be for blind navigation, particularly of aircraft. Blind bombing suggested itself automatically because of the apparent imminence of war in Europe.

However, if delay times equivalent to tens or even hundreds of miles instead of tens or hundreds of feet were to be measured, it was apparent that two requirements would immediately present themselves. First, a round-trip signal between the two points of distance determination would have to be used. This would call for either an extremely efficient reflector at one end of the path or for retransmission of the original signal at the path terminal. Second, some type of vernier or decimal indication would be necessary in order that the radio "yardstick" could be read to, say, ±100 feet even though the round-trip or total distance was of the order of 2,000,000 feet or 400 miles.

Many experiments were performed in the fall of 1938 and the spring of 1939 to confirm the belief that relatively long distances could be measured with even higher absolute accuracy, and thus perhaps a thousand-fold greater proportional accuracy, than the original television multipath determinations.

One interesting experiment consisted of retransmitting the television pictures from the Empire State Building between

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two points on Long Island separated in such manner that the relayed picture arrived at a receiver almost exactly one line later than the direct signal. The raster on the cathode ray tube face was synchronized continuously with the direct signal from National Broadcasting Company while the video content was commutated between the direct and relayed pictures. When the relayed signal path length corresponded exactly to one line, the commutation process produced no horizontal jitter of the television image. The signal was, of course, delayed in the relay terminal equipment by the electric inertia of tuned circuits, video amplifiers, and connecting cables. These time intervals had to be taken into account, and those which could not be accurately calculated were measured by a determination of the phase shift characteristics of the modulation components of an r-f signal passing through the equipment. It is interesting to note that the total time elapsed in the relay receiver and transmitter corresponded to a path length of nearly 2,000 feet. But since it could be accurately measured to within 0.01 microsecond by the slope of the phase versus modulation frequency characteristic, errors from that source were not more than ±10 feet. It was necessary to call on the U. S. Coast and Geodetic Survey for accurate ground distance information.

The results of that experiment and others were convincing proof that a radio "yardstick" could be constructed for first-order determination of distances out to the limits of propagation of the radio frequencies used. The latter had to be relatively high to accommodate the rapid modulation necessary for sharp time indications. Amplitude or frequency changes in the radiated wave would have to occur in the order of 1/10 microsecond if measurements with an accuracy of that order were to be possible. This called for a transmission frequency whose fundamental period was not more than 1/50 microsecond or a minimum 50 megacycles.

The transmission of what could be termed single picture elements, one at a time, with the transmitter completely quiescent between those pulses, was chosen as the most practical mode of operation. Such a system would allow relatively high power radiations with relatively low average power consumption. This principle, decided upon in October of 1938 for the original Shoran development work, has been used almost universally in all radar equipments whose function requires operational ranges greater than one or two miles.

It is not meant to imply that this date marked the first concept of pulse type operation. However, the choice of pulse type operation at that early stage of the Shoran work marked the final equipment for success. Attempts to derive the same end results by other systems have proved the wisdom of that choice.

During 1939 many types of possible vernier time measurement devices were conceived, built, tested, and discarded. Since it seemed certain that on occasion multiple pulses, due to reflected waves traveling devious paths, would arrive at the receivers at each terminal of the transmission path, and since, obviously, the first pulse to arrive would be the only one to give an indication of the direct path distance, it seemed clear that a cathode-ray-tube type of data presentation would offer the simplest means of discrimination between the desired or first-arriving information and subsequent indications. It was conceivable that circuit arrangements could be effected whereby the elapsed time could be indicated on meters or transposed to data transmission systems. However, the most straightforward procedure appeared to lie in the use of linear determinations of the position of an alteration in either the intensity or deflection of a cathode ray tube trace.

Here again this early choice of the cathode ray tube as the indicating element has certainly been vindicated by subsequent developments. Much later in the history of Shoran, circuits were developed for transferring the derived information to a data transmission system. This made it available at positions remote from the equipment; but those circuits, which will be described later, are of only secondary importance, and the cathode ray tube remains the prime indicator.

Two further principles, each of which contributed markedly to the success of Shoran, were also adopted early in its history. First, the repetition rate of the transmitted pulses, which could be controlled by quartz crystal oscillators to an accuracy of one part in 1,000,000 if necessary, was selected as the fundamental unit of measurement. Second, an old principle familiar to precision instrument makers in many fields and known as the set-back type of operation was adopted. This principle is exemplified in precision aneroid barometers wherein movement of the bellows caused by varying air pressure is counteracted either by adjustable weights or by adjustable spring tension sufficient to return the bellows distortion to a fixed zero. The weights or the spring adjustment necessary to perform that function then give an indication of the air pressure. While this type of operation seems cumbersome compared to the simpler method of causing the bellows to move a pointer around a calibrated scale, actually the increased precision is well worth the complexity.

As applied to Shoran, this system eliminates the need for the maintenance of exact linearity of the cathode-ray-tube sweep speeds in the presence of varying power line voltages, varying vacuum tube characteristics, and varying circuit parameters. So far as is known to the author, Shoran is the only radar system which adopted the continuous set-back principle. However, the advantages which accrue from its use are not as necessary in equipments which seek less inherent accuracy.

By the summer of 1939, enough experimental and developmental work had been done to indicate the probable practicability of a blind bombing navigational device founded upon the principles enumerated above. Operation would call for an equipment in an airplane which could simultaneously measure its exact distance from two separated and accurately known ground locations in friendly territory while the plane flew over enemy targets. Investigation revealed that all of Europe, together with all of the North American continent, had been sufficiently well mapped so that the distance between any two points within 250 miles of each other in those parts of the earth could be calculated with a probable error of 50 feet or less.

Armed with this information, and fortified with the confidence of many months of satisfying experimental endeavor, the project was presented by Radio Corporation of America to the United States Army Air Forces with the proposal that funds be allocated for the development of operating models of the necessary equipment to test its feasibility. That was in the summer of 1940.

It is an interesting commentary on the thinking of those times that the author felt constrained to write into the specifications of the proposal the suggestion that the probable accuracy of distance measurements would be of the order of ±500 feet. These predictions, definitely pessimistic in view of the favorable experimental results in the laboratory, were made pessimistic principally because it appeared utterly fantastic at those times to presume to achieve even that goal. To have suggested more would have branded

the project as completely unrealistic.

Even with those moderate claims, the apparent unreality of the proposed program hindered the progress and retarded the growth of Shoran up to the very day the first Shoran bombs dropped to destroy a 30-foot-wide enemy-held bridge in northern Italy.

War in Europe had been declared at the time of these first proposals. The pace of preparedness in the United States quickened after the fateful September 1, 1939. More money was allocated to the armed services for development of new devices, and even some of the projects which were felt to be a bit on the fantastic side were given the green light.

Accordingly, a contract was awarded to RCA Laboratories in February of 1941, about nine months before Pearl Harbor. This called for completion by February 1942 of two ground station equipments and one airborne equipment to give simultaneous and continuous distance determinations from each of the ground stations to a plane, out to optical line of sight, with an accuracy not poorer than −500 feet at 100 miles or 0.1 per cent of the distance beyond that point.

The 2 1/2 years of experimental work before the awarding of the contract had allowed the plans for the model to be so well formulated that just four months later the plane equipment and one ground station were completed and ready to operate. With one complete operating chain, many previously unanswered questions could be resolved. One determination which had not been made concerned the possible variations in the propagation velocity of a radio wave at tangency with the earth's surface. It appeared that vegetation and partially conducting soil with a high dielectric constant could well have a marked effect on that all-important characteristic. Also the probable variation caused by changes in the humidity of the air was a possible source of difficulty which could only be crudely calculated. Accordingly, it was decided to place the plane equipment in the tower of the Empire State Building, put the ground station out beyond the optical horizon at Rocky Point, Long Island, and make day-to-day measurements of the distance between the two points. This was done after flight tests from Wings Field near Philadelphia, Pa., to the Rocky Point location had confirmed adequately the predicted range of operation.

Measurements between the Empire State tower and Rocky Point were continued for a period of three months during the summer of 1941. Hundreds of readings were taken and the equipment operated by many different observers. During that time the temperature varied more than 40 degrees Fahrenheit and the humidity ranged from a low of 30 per cent to a high of 100 per cent. An average of all readings indicated a distance of 56.126 miles with a total spread of 0.013 mile. There was no apparent correlation between climatic conditions and the readings. Later the United States Coast and Geodetic Survey gave the measured distance as 56.127 miles, or five feet more than the average of the Shoran readings. Obviously the transmission path to the Rocky Point location, which was 400 feet below optical line of sight, through scrub pines and over sand, was not affecting the velocity of propagation to any marked extent over and above the variations caused by normal sea level air pressure. The latter had been calculated beforehand and introduced into the equipment as a correction to the frequency of the crystal-controlled pulse repetition rate. The agreement between the Shoran and geodetic distance measurements was actually too close for comfort. Had they differed by 200 feet or so, they could have been given to the Aircraft Radio Laboratory as evidence of the potentialities of the system. Under the circumstances, it was decided that it would be best to say nothing about that particular series of measurements and let the contracting agency make its own accuracy determinations.

At the time of Pearl Harbor, the Aircraft Radio Laboratory took delivery of two specially constructed all-metal trailers which they had ordered built to specification to house the Shoran ground stations. Each of these had its own 5-kw gasoline-driven a-c generator in a glass-enclosed gas-tight compartment. These were in turn delivered to the RCA Communications Laboratory at Rocky Point and the Shoran gear installed. Further tests followed with the ground stations operating as complete self-contained mobile units. Then shortly before the contract expiration date, the entire equipment was sent to Wright Field for acceptance tests.

It is well to bear in mind the particular conditions which existed at that time. The United States had been at war for just 2 1/2 months. The mad rush to prepare for the titanic struggle which was already upon us called for emphasis on the most necessary fundamentals first. Communication radio and liaison equipment for a rapidly expanding air force were requisites of prime importance. The Aircraft Radio Laboratory at Wright Field was so completely occupied with the specification and procurement of these necessities that they had neither time nor facilities for acceptance tests of such apparently obtuse devices as Shoran. It was not until six months later, in August of 1942, that the original plane equipment was mounted in a B-17 Flying Fortress and taken to Eglin Field, Fla., for bomb-dropping tests. The mobile ground stations were set up at Montgomery, Ala., and at Tallahassee, Fla. In order to save time, the distances from each ground station to the 30-foot square-base pyramid target in the bay near Eglin Field were determined by flying over the target with a Norden bombsight set to vertical and reading the Shoran distances. This process was repeated several times, but the pitch and roll of the plane, together with the inability of the automatic pilot to do a precise job of following the bomb sight lead, resulted in considerable discrepancy between successive readings. Admittedly the bomb-dropping trials were to be handicapped, not only by the possible Shoran errors but by those of the Norden bombsight and automatic pilot as well. The distances finally determined were 108.297 miles to Tallahassee and 125.431 miles to Montgomery.

Of the first 12 100-pound sand-filled practice bombs dropped from 14,000 feet, the average dispersal from the target was 220 feet. Two of the bombs hit the 30-foot-square wooden target. The results were on a par with those to be expected from a mission dropping the same number of that type of bomb by visual means. The ballistics of sand filled practice bombs are erratic in comparison with those of heavier missiles. Additional tests were made from 20,000 feet and the results were relatively the same. It appeared that Shoran had proved its capabilities as a blind bombing device even before its precision for distance measurements had been evaluated.

The procedures developed for determination of the release point of the bomb on those early test runs are interesting. It would be beside the point to go into all the ramifications of the calculations of bomb trajectories and release points in this paper. Suffice it to say that the vector winds through which the plane was passing were determined by comparing the indicated air speed of the plane with the rate of change of Shoran distances for a given plane heading. Manual release at the proper point was effected by the simple process of pressing a button connected electrically to the bomb rack intervalometer. Human reaction time was not considered a factor because of the

anticipatory knowledge constantly supplied by the Shoran indications. Later production models were equipped with devices which automatically measured the plane speed as well as the vector wind, made the required corrections in the ground path of the plane, and automatically released the bomb at the corrected point on that path. That portion of the equipment was developed primarily by F. J. Hooven in co-operation with engineers of the Harris Seybold Potter Company under contract to the Armament Laboratory of the Air Technical Service Command. It is a marvel of ingenuity and precision, but at this writing, information regarding the details of that device is still restricted.

After the Eglin Field tests, it seemed certain that an immediate request for product designs and production schedules would be forthcoming. Much to the personal disappointment of those who had nurtured the development from its conception, such was not to be the case. Interest in blind bombing devices was at fever heat, but the new microwave techniques were coming on the scene and their freedom from any tie to fixed locations on the ground seemed to offer the only complete answer. Actually it was not until after the close of war in Europe that it was determined that 80 per cent of all strategic missions and almost 100 per cent of all tactical missions flown in that theater were within the Shoran range of operation.

A further deterrent to Shoran progress lay in the fact that by then the British had started development of a somewhat similar system and it was felt inadvisable to carry on two separate product design and procurement programs without coordination. Accordingly, a small group of military personnel headed by Lieutenant Colonel R. R. Brunner, together with two Radio Corporation of America engineers, left for England on December 1, 1942, to exchange information and to resolve the degree to which the two programs could be integrated. However, the work carried on at Telecommunications Radio Establishments under the Air Ministry was based on entirely different principles than those of the Shoran development and there appeared to be no common basis upon which the two programs could be combined.

On the return trip from England, the party split into separate groups. The group consisting of Colonel Brunner and some British military personnel coming to the United States to get a better picture of the Shoran project was lost in flying the South Atlantic Ocean. Viewed in retrospect, it seems certain that this loss was a major factor in keeping Shoran progressing at a snail's pace toward its ultimate conclusion.

Finally in March of 1943 a product design contract was given to RCA and work progressed again at full steam. The contract stated that the ultimate equipment should have an accuracy of distance measurement at least equal to that of the original model which, by then, carried the army designation SCR297-T2. It was realized by all concerned that the ±500 feet specification was so pessimistic as to be meaningless, so no figures were mentioned. Several of the automatic features referred to previously were specified as essential to fulfillment of that contract.

That work was completed in January of 1944. It is a credit to all concerned to say that the faith of the Air Technical Service Command Aircraft Radio Laboratory in the ultimate outcome of that program was such that they recommended, and Radio Corporation of America received, large procurement orders well in advance of its completion. Thus the Shoran radar program acquired the unique distinction of having been conceived, developed, product-designed, and manufactured entirely within one company. This, of course, neglects the auxiliary equipment mentioned above.

After the completion of the design work, and while waiting for production quantities to become available, a six-month program of rigorous flight and field tests was inaugurated at Boca Ratan, Fla., under the auspices of the Aircraft Radio Laboratory. For the first time, a true indication of the accuracy of distance measurements from a plane to a fixed point on the ground was available. This was derived by the use of so-called Zenith cameras located at known control points approximately 100 miles from the Shoran ground stations. The plane was equipped with a gas-filled flash lamp on the under side of the fuselage. As the plane passed over the Zenith camera, the lamp was flashed and the Shoran distance readings recorded. Many nights of such flights with many passages back and forth across each new Zenith camera location gave sufficient data to indicate the probable error of distance measurement as being somewhat less than 50 feet out to the limit of its range. Hundreds of bombs were dropped and many different operators acted as Shoran bombardiers. As a matter of fact, no single individual ever dropped enough bombs to become really proficient in the use of the equipment, but the design was such that it was relatively simple to operate. Thus, human errors, particularly when the operator had had training on a Norden bombsight, were at a minimum.

The extreme accuracy of distance determination attracted the attention of the Army geodetic and mapping groups. As a result of their interest, the equipment is being used today for establishing control points with first-order survey accuracy at very great distances. For this work a ground station is established at each point to be located and a plane flown back and forth across the line between any two such points. The average minimum sum of the distances between the plane and each ground station, as indicated by a photographic recorder for each line crossing, gives the true distance between the points. The comparative simplicity of surveying a line from, say, Chicago to Kansas City to Amarillo, Texas, in only two jumps can be imagined. For a survey of that route, three ground stations would be used, one at each of the three cities, and 10 or 20 flights back and forth across the approximate center of each line would be all that would be required. Except for one consideration, it would be unnecessary for any individual to set foot upon the intervening terrain. Subsequent to the early tests between the Empire State Building and Rocky Point, the true effect of climatic conditions on propagation velocity and on the refraction of the radio waves between plane and ground had been determined. As a result, sounding balloon or other types of atmospheric determinations along the path are considered necessary when the equipment is used for first-order survey work. Nevertheless, the simplicity and rapidity with which unmapped portions of the surface of the earth can be brought into survey control with equipment of this type is little short of amazing.

At the completion of the Boca Ratan tests, the remarkable results achieved became known to the commanders in the fields of operation and requests for equipment began to pour in. In September of 1944, it was decided to test the equipment in actual operation against the enemy. Several personnel from the Aircraft Radio Laboratory and the Armament Laboratory (also at Wright Field) were accompanied to Corsica by three Radio Corporation of America engineers to aid in setting up the equipment and to train ground and air crews in its use over northern Italy. There were many disappointing delays in the arrival of the equipment. Boxes supposed to contain transmitter tubes were found to contain toilet necessities and flashlight batteries.

Figure 1. The Principle of Shoran

The Shoran set indicates plane's distance from two ground stations, thus "fixing" it at intersection of the corresponding circular arcs swung around the two stations

More weeks followed during which crews were training and practice bombing. Finally on December 11, 1944, the first Shoran bombs were dropped. From that time on, events moved with rapidity. Operational results were phenomenal. Bridges that had withstood many close misses by visual missions were destroyed on the first Shoran run. Weather was no hindrance to tactical air support with Shoran. By the time the war ended in Europe, the amount of tactical bombing being done in any area was predicated almost entirely upon the availability of Shoran equipment. By the time the war with Japan was brought to a close, the plans of the Army and Navy for the use of Shoran in the Pacific were astounding even to those who knew its potentialities.

The Shoran System

Figure 1 shows the 2-distance "fix" method used by Shoran to locate a position in flight. The airplane equipment transmits a series of short pulses of radio frequency energy to each of a pair of ground stations. These in turn immediately retransmit the received signals to the plane where the round-trip transmission time is measured in terms of distance. In bombing operations the plane flies in either direction on an arc about one of the ground stations. The radius of the arc is equal to the station-to-target distance. Since either ground station may be used as the center of the flight path, four different approach headings are possible when bombing a given target. With normal station-to-target distances, the curvature of the bomb run path is relatively slight. A refined type of pilot direction indicator meter, deriving its information automatically from the equipment, is in front of the pilot. During a bomb run, with the aid of this instrument, it is not difficult to keep the plane on its arc path with deviations less than the span of the plane wings.

It should be noted that no information is passed along the path joining the ground stations. If the geographic locations of those stations, as well as those of all possible targets, are accurately known, as was the case in the European use of Shoran, the geodetic problems connected with Shoran operations are relatively simple of solution. When they are not known, Shoran reconnaissance photography of possible targets will reveal their co-ordinates.

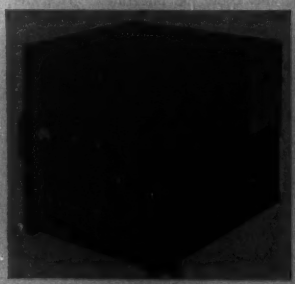
It is highly desirable that a pair of ground stations be able to serve a large number of planes bombing widely separated targets simultaneously. This is possible with Shoran installations, and the means by which it is accomplished without interference will be described later in this article.

Planning of a Shoran mission, with all the geographic distances known, is not as simple as it might at first appear. The great circle path of a plane several thousand feet in the air differs from the great circle path on the earth's surface, often by as much as one tenth mile. Contrary to a widely held belief, radio waves do not travel in a straight line over any appreciable distance, but tend to be refracted into a vertical arc. Radiant energy travels faster at bomber plane altitudes than it does through sea level air pressures. Fortunately, all of these effects are predictable accurately, and all are taken into account in determining Shoran co-ordinates for a given bombing mission. The calculations involved are completed before take-off. In bombing operations, possible corrections indicated by variations in climatic conditions are usually of insufficient magnitude to be significant.

The ruggedness and relative simplicity of operation of the components of a Shoran system, together with the freedom from equipment failures which it provided in combat use, are all remarkable in view of the extreme precision of the results obtained. Details of the individual portions of the equipment are given herewith.

Figure 2. Panel of timing and indicating unit of Shoran plane equipment

Figure 3. The airplane transmitter



The Plane Equipment

The principal units of a Shoran plane equipment are shown in Figures 2 and 3. Figure 2 shows the timing and indicating device which is the most vital part of the Shoran system. This unit permits regulation of the timing of the transmitted pulses in such manner that the signal returned by retransmission from the ground arrives back at the plane receiver and makes its appearance on the screen of the cathode ray tube coincidentally with the fixed, or so-called T_0 marker indication. The adjustment necessary to effect this coincidence is calibrated in miles and decimal portions of a mile. Thus the mileage indications are read from the dial settings rather than from the face of the cathode ray tube, in accordance with the set-back principle referred to previously.

The pulse timing function is duplicated in the indicator unit to allow for simultaneous distance measurements from two ground stations. Reference to Figure 2 will show the two large 100-mile dials at the bottom of the panel. At the left of each dial is a Veeder-type counter, the three digits of which indicate miles, tenths of a mile, and hundredths of a mile. Estimation to the nearest 1/1,000 of a mile is possible. Adjustment of each of the two sets of distance indicators is made by rotation of the small hand wheels to the left and slightly below the large dials. In the case of a plane in motion, continuous rotation, achieved by variable speed motor drive, can be imparted to the shafts carrying the hand wheels, thus keeping the indicated data up to date. It can be readily understood that the rate of rotation necessary to maintain coincidence between the received signal and the T_0 marker is of value in determining the plane's ground speed and in the calculation of bomb release points. Beyond 100 miles the readings are repeated. Thus the readings would be the same for distances of 57, 157, and 257 miles.

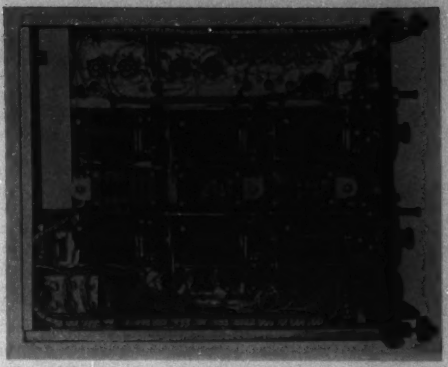


Figure 6. Bottom view of timing and indicating unit

Each goniometer is mechanically connected through reduction gears to the others in the chain

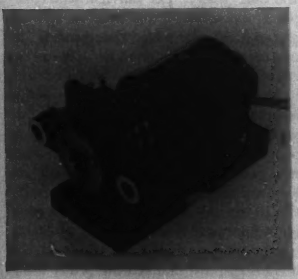


Figure 4. The goniometer which determines Shoran timing

Figure 5. Goniometer with rotor withdrawn

The Faraday screen of copper ribbon covers the crossed windings of the stator

The most interesting portions of the timing and indicating circuits are those which control the timing of the transmitted pulses. The accuracy of that function depends upon the stability of a quartz crystal oscillator operating at 93,109 cycles per second. It should be noted that this figure is exactly one-half of 186,218, which is the number of miles traveled each second by a radio wave passing through sea level air pressure. Thus the period of one cycle of the oscillator is equivalent to the time required for a radiated signal to travel a *round-trip* distance of one mile.

The voltage output from the oscillator is distorted in vacuum tube circuits by clipping and differentiation processes to form a very short pulse, accurately located at a fixed phase of the cycle. This is passed to the cathode ray tube and becomes the T_0 marker on the screen. The output of the 93-kilocycle oscillator is also split into two accurately spaced quadrature components and delivered to the crossed windings of the stator of a goniometer. Pictures of this unit are shown in Figures 4 and 5. The rotor of the goniometer can be turned throughout 360 degrees, and the output potentials, derived by way of the slip rings, have a phase corresponding to the position of the rotor. This potential is likewise clipped and differentiated and produces a pip which then can be timed accurately to any point midway between two marker pips. One degree of rotation of the goniometer corresponds to a round-trip path length of 15 feet. If these adjustable pips were all used to actuate the transmitter, there would be several hundred transmitted impulses stretched out over the round-trip path between the plane and a ground station, and confusion would result. Therefore, it is necessary to select *one* pulse out of each 100 that are developed and discard the others. Accordingly, the 93-kilocycle wave is passed to a 10:1 phase degenerated frequency divider and the new frequency split into quadrature components for a second goniometer. This unit is mechanically connected to the first goniometer through 10:1 reduction gears. The resultant output is used as a gate to select one out of each ten of the developed pips. Again the process is repeated with another 10:1 divider, and a third goniometer is driven by the second through another 10:1 reduction gear. The final output voltage at 931.09 cycles selects one of the ten previously selected pips and thus discards all but one of the original 100 which were developed. The second and third goniometers have no effect on over-all accuracy if the output phase of each is correct within the selection limits of ± 15 degrees. Greater discrepancies would produce errors of exact multiples of one mile or ten miles, depending upon which of the two units was at fault. The circuits which deliver the

Figure 7. The Shoran receiver used in both plane and ground stations

quadrature currents to the goniometers are unique in one important characteristic. Large changes in the power factor of the stator windings produce no phase variations of the currents which flow through them. Thus temperature compensation is unnecessary, and ambient temperature variations from −70 degrees Fahrenheit to +140 degrees Fahrenheit make no readable change in indications. The complete chain of goniometers, mechanically coupled through reduction gears and supplied with the proper energy from the associated circuits, permits accurate placement of the transmitter pulse to within 1/100 of one degree of any position throughout the 100-mile repetition rate cycle. This is accomplished without excessively close tolerance specifications on any parts of the equipment. The twin rows of goniometers can be seen in the bottom view of the timing and indicating unit chassis in Figure 6.

The two timing devices are completely independent of each other, and the transmitter control is commutated between them approximately ten times per second.

During the commutation cycle, the frequency of the transmitter is altered so that all pulses sent out in accordance with timing derived from the left-hand control are on one wave length, while those from the right-hand control are on another. Thus each of the two ground station receivers can pick up and retransmit the signals meant for it and discriminate against those intended for the other. The commutation process also switches the gain control function of the plane receiver alternately between two potentiometers, each of which can be adjusted separately. This allows for wide differences between the strengths of signals received at the plane from the two ground transmitters, as is the case when operating close to one but remote from the other.

One other function of importance is performed during the commutation cycle. In order to operate many planes in the air at once and have them all use the same pair of ground stations, it is necessary that transmission from a ground station to one plane not interfere with the proper operation of Shoran equipment in another. Since the repetition rate of Shoran pulses is the precise yardstick in terms of which the distances are measured, all planes utilizing a pair of ground stations simultaneously will be using that same yardstick. Thus it would be possible for the accurately synchronized indications from a ground station, meant for one plane, to be picked up by another and give the second plane crew an erroneous indication of their position. This possibility is obviated by an action of the commutator during a third portion of the one-tenth-second period of its cycle during which *no* transmissions occur. During this time, the repetition rate circuits of the timer are momentarily blocked off and then immediately allowed to resume operation precisely at the previous rate. The result is that no two plane equipments interrogating a common ground station can stay synchronized for more than a small fraction of a second, in spite of the fact that their interrogation rates are precisely the same.

The trace on the cathode ray tube is circular. There were two reasons for this choice. A 3-inch tube will accommodate a $7^1/_4$-inch circular trace compared to a $2^1/_2$-inch linear sweep. Also a circular sweep is continuous without breaks in its continuity while the spot returns to its starting position. A throw of a switch changes the deflection rate of the circular pattern from a 1- to a 10- to a 100-mile scale. For navigational purposes, out to the initial point of a bomb run, the 100-mile scale is adequate. The use of this scale allows the operator to effect coincidence of the received and marker pulses to well within the ±5-mile interval over which they are visible on the ten-mile scale. He can then repeat the process and switch to the one-mile scale. Thereafter, if the data are kept up-to-date, he need not return to the 10- or 100-mile scales, since the complete information is constantly available on the mileage dials. All traces on the oscilloscope are blanked out when using the 1- or 10-mile scales except for the particular 1- or 10-mile interval containing the T_0 time. Actually, the T_0 marker is traced on the screen for the 1- and 10-mile scales during an unused portion of the 100-mile repetition rate. Thus, the received pulses, which are outward for the left-hand mileage controls and inward for the right-hand dials, appear to be superimposed upon the marker deflection rather than to mingle with it and thus cause confusion. Matching is correct when the left-hand (leading) edges of all pulses are coincident.

The plane receiver controls are on the separate oblong panel extending upward

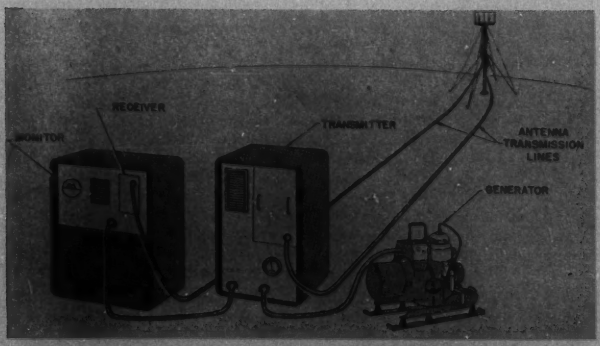


Figure 8. Units and cabling of ground station

slightly to the right of center in Figure 2. The receiver can be withdrawn and replaced in a matter of only a few seconds in case of defective operation. All connections, with the exception of the antenna, are made through sliding contacts and are thus automatically broken and reestablished when the unit is removed and replaced. One of the filters for the forced air cooling system can be seen in the upper left-hand corner. Figure 7 shows a receiver withdrawn from its compartment.

Figure 3 shows the plane transmitter which generates the signals radiated under control of the timing and indicating unit. It is usually mounted in some out-of-the-way position in the airplane, since it has no adjustments that need attention while in flight. "Start," "stop," and "standby" operation are remotely controlled by relays actuated in conjunction with those of the timing and indicating unit.

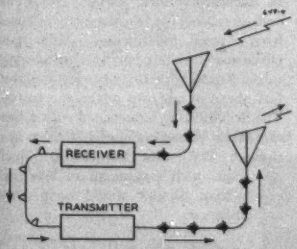


Figure 9. The function of the ground station
Pulses received from the airborne transmitter are amplified and retransmitted to the plane

The peak power input to the transmitter tubes is approximately 50,000 watts, and a plate circuit efficiency of about 30 per cent is realized. The low operating duty cycle results in an average plate power consumption during operating periods of only 30 watts. Positive plate, or B voltages, are not used on the two push-pull self-oscillating transmitter tubes which derived their plate energy entirely from the 5,000-volt positive swing of the secondary of the pulse modulation transformer. The two transmitter frequencies, which are commutated during operation, are adjustable in the region of 220 to 260 megacycles. Usually they are separated by from five to ten megacycles, but they must correspond to the respective ground station receiver frequencies. Commutation of the radiated wave length is made possible by the action of a solenoid-operated vacuum-contact short-circuiting bar on the resonant grid line of the oscillators. The adjustment of the position of that bar and of all other grid and cathode line connections is controlled by screw driver adjustment through the front panel. The plates of the oscillators are at radio frequency ground potential.

The antenna for radiating the transmitter power is of the stub type and is mounted vertically either above or below the fuselage. An attempt is made to produce as nearly an omnidirectional pattern of vertically polarized radiation as possible. The antenna proper is somewhat unconventional. It consists of a center rod extending approximately 1/8 wave length beyond a 1/8-wave grounded concentric sleeve. The entire assembly is about 12 inches in length. In operation the antenna has relatively broad band characteristics and produces a low order of standing wave ratios on the 50-ohm transmission feed line throughout the transmitter frequency range.

The plane receiving antenna is of the same type of construction but is somewhat shorter in over-all length, since it receives signals from ground stations which transmit on approximately 310 megacycles.

Lengths of interconnecting cables between units and between the transmitter and receiver and their respective antennas have an effect on the total time spent by pulse energy in traversing all of the plane equipment circuits. Therefore, each plane installation must be compensated by a process which involves the sending of test signals around the complete loop and making the necessary corrections in the position of the marker pulse. Actually, the adjustment is not made to zero but to a standard negative value of distance which compensates for all of the fixed delays in the ground station as well as for those in the plane. Thus, if the intervening path between the plane antennas and those of the ground station were of zero length, a pulse initiated in a timer chain reading zero would pass through the plane transmitter, all the ground equipment, and finally arrive back at the plane receiver in time to appear on the cathode ray tube exactly superimposed upon the T_0 marker. The point which bisects an imaginary line drawn between the plane transmitting and receiving antennas is that from which all measured distances are indicated.

Figure 11. Panel of ground station transmitter

The Ground Station Equipment

A ground installation consists essentially of four principal units. These are the receiver-monitor, the transmitter,

Figure 10. Panel of ground station monitor-receiver

the antenna arrays, and the gasoline-driven power supply. See Figure 8. The complete equipment is air-transportable and can be flown to a known location and put into operation within 90 minutes after arrival.

The primary function of the ground equipment is to receive, reshape, and retransmit all pulses arriving at the location on the particular wave length to which the receiver is tuned. See Figure 9. The elapsed time between the arrival of a signal at the receiving antenna and the radiation of the resultant pulse from the transmitting antenna must be accurately adjusted to a fixed standard time interval. That adjustment, as well as others necessary for proper operation of the installation, is performed with the aid of the monitor portion of the monitor-receiver unit. This is shown in Figure 10.

The oscilloscope in this piece of the equipment facilitates adjustment of frequency dividers which regulate the timing of standard repetition rate radiations independently of any received signals. These are under the control of an extremely accurate 93, 109-cycle temperature-controlled crystal and allow a plane equipment operator to make a slight adjustment in the frequency of his crystal if temperature or other conditions have caused excessive drift. Continuous radiation of standard pulses from the ground also enables the plane operator to tell whether or not he has sufficient altitude to be within range of that station even before he starts transmitting.

Figure 12. Ground station antenna assembly

The adjustment of the total delay interval to the standard value is made by varying the number of delay line sections in the circuit until the loop-delayed pulse matches another which is passed only through a standard delay network.

The receiver, shown on the right-hand side in Figure 10, is identical to, and interchangeable with, the receiver in a plane equipment. It has a continuously adjustable tuning range between 210 and 320 megacycles.

The transmitter, shown in Figure 11, is very similar to that used in a plane. However, it has a much higher duty cycle, when serving a large number of planes, and the modulator circuits are, therefore, made heavier to handle that load. Whereas the average plate power in a plane transmitter is 30 watts during operation, the ground transmitter may be developing as much as 400 watts. Each develops a peak input power of about 50 kw.

The transmitting and receiving antennas are shown in Figure 12. The reflectors give power gain of approximately eight to one in the forward direction with a horizontal coverage angle of about 70 degrees to the half-power points. The whole assembly is supported on a 50-foot sectionalized plywood mast.

The gasoline-driven generator delivers about 1,500 watts at 115 volts, 400 cycles, and approximately 400 watts at 28 volts direct current.

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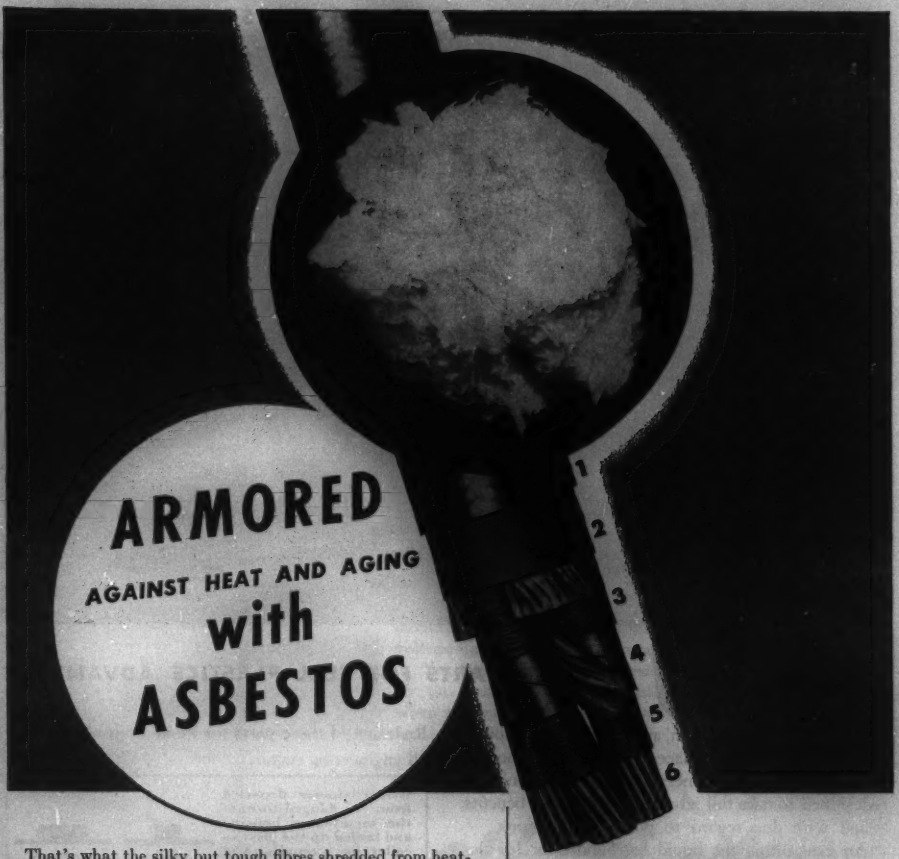

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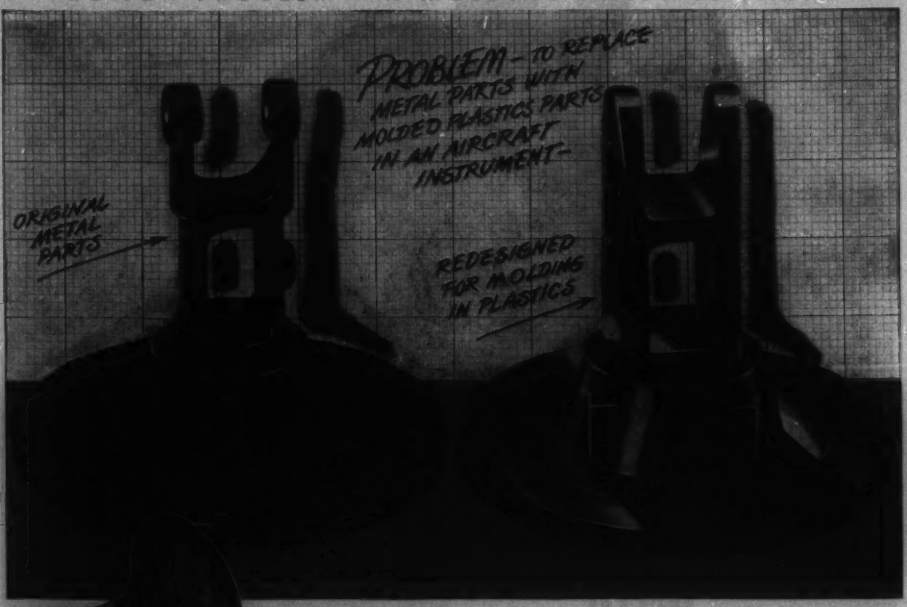
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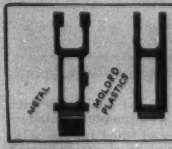

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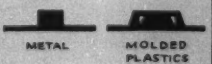

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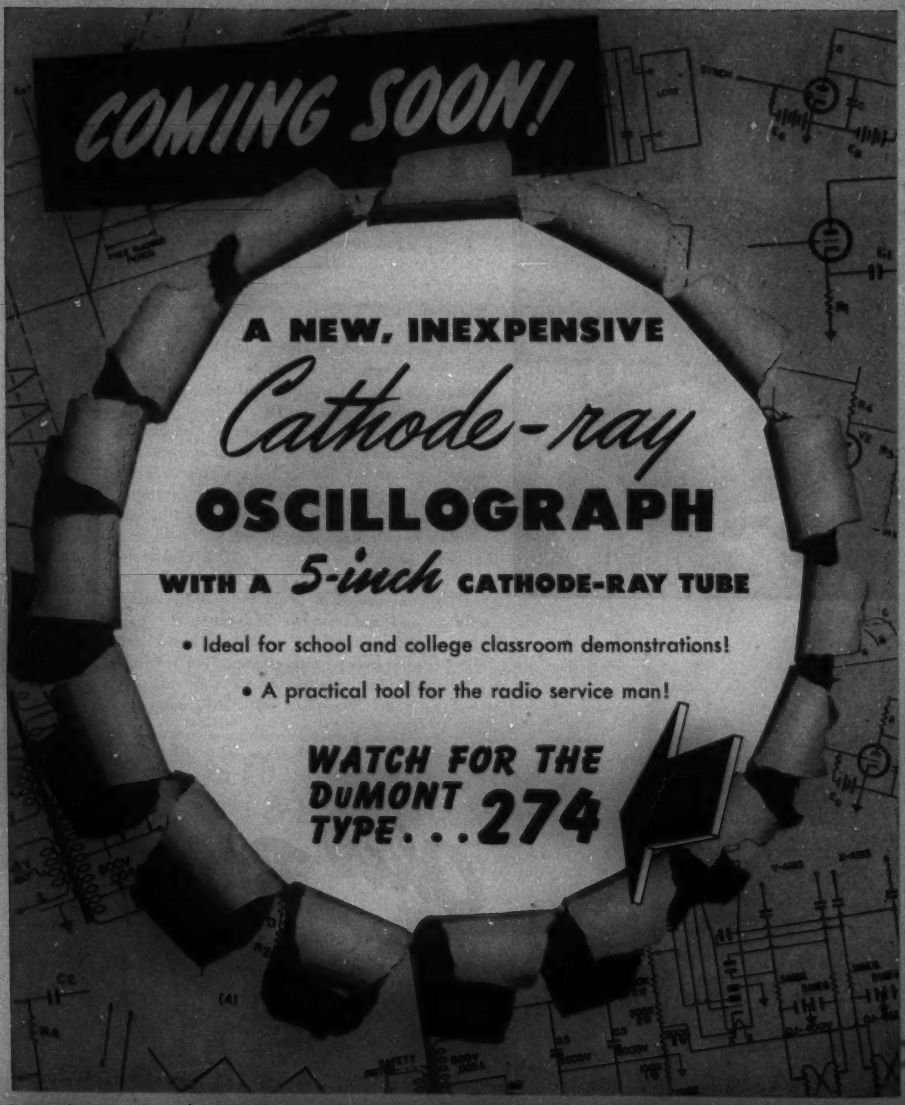

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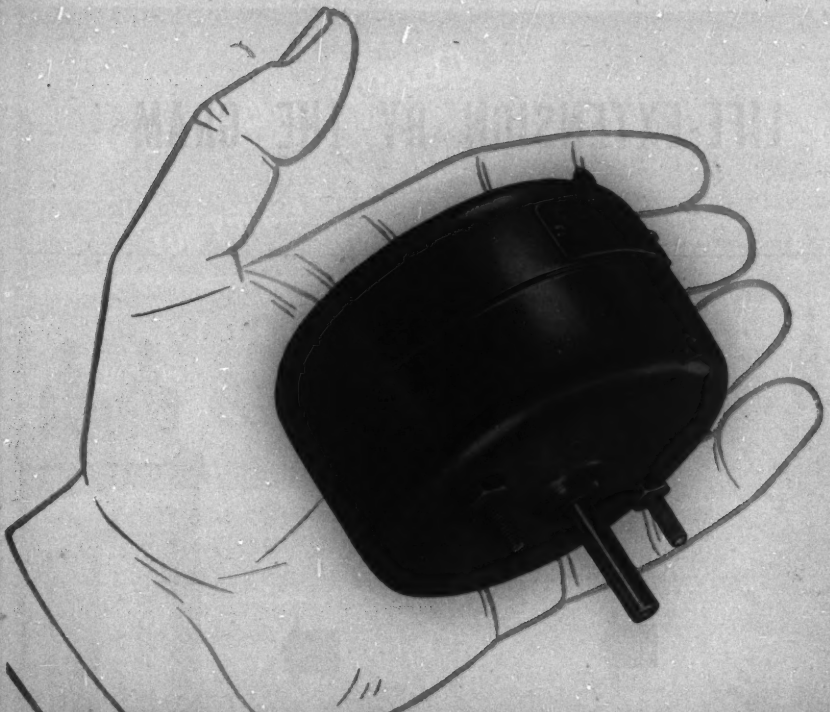

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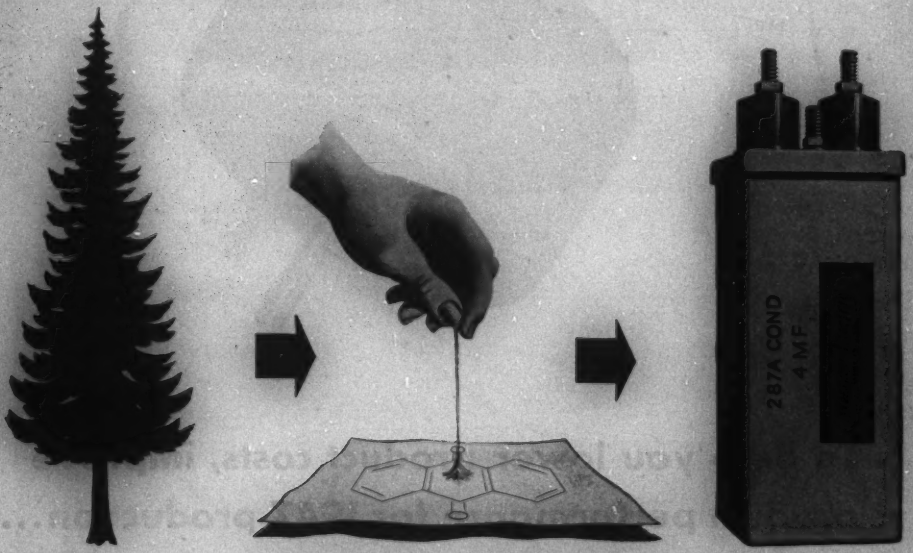

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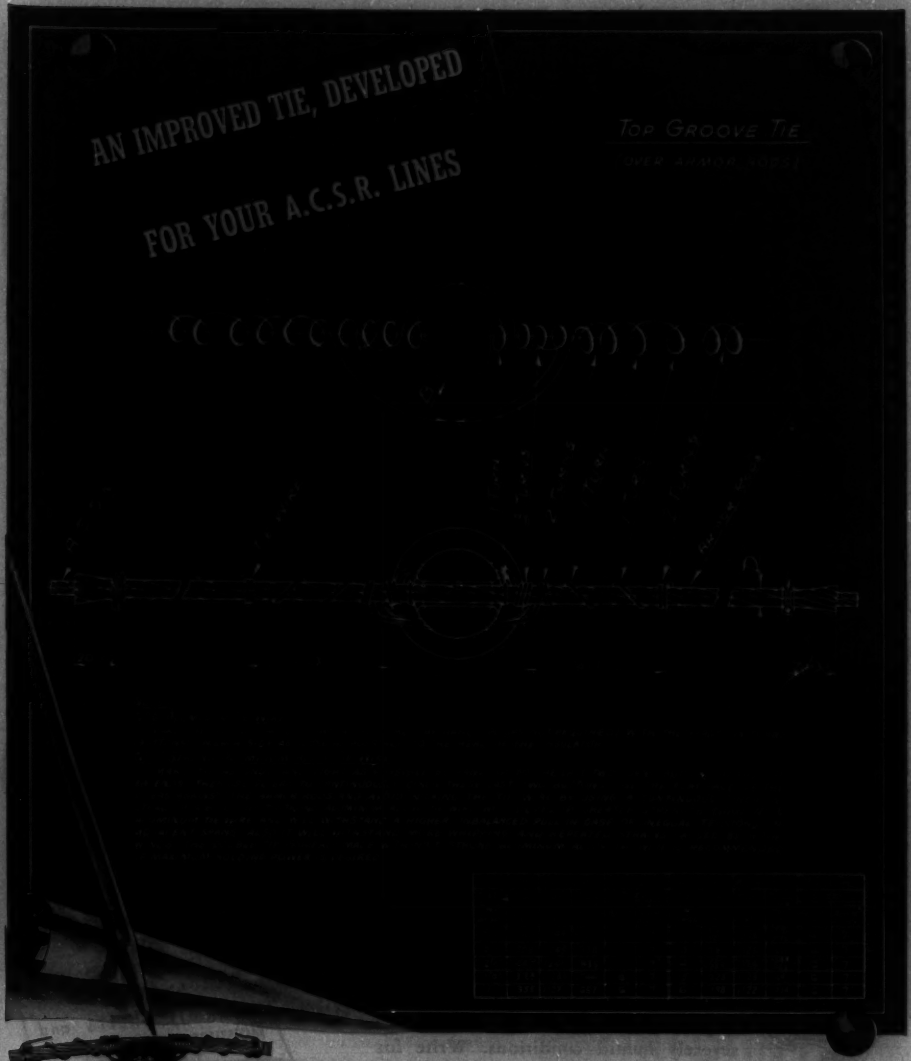

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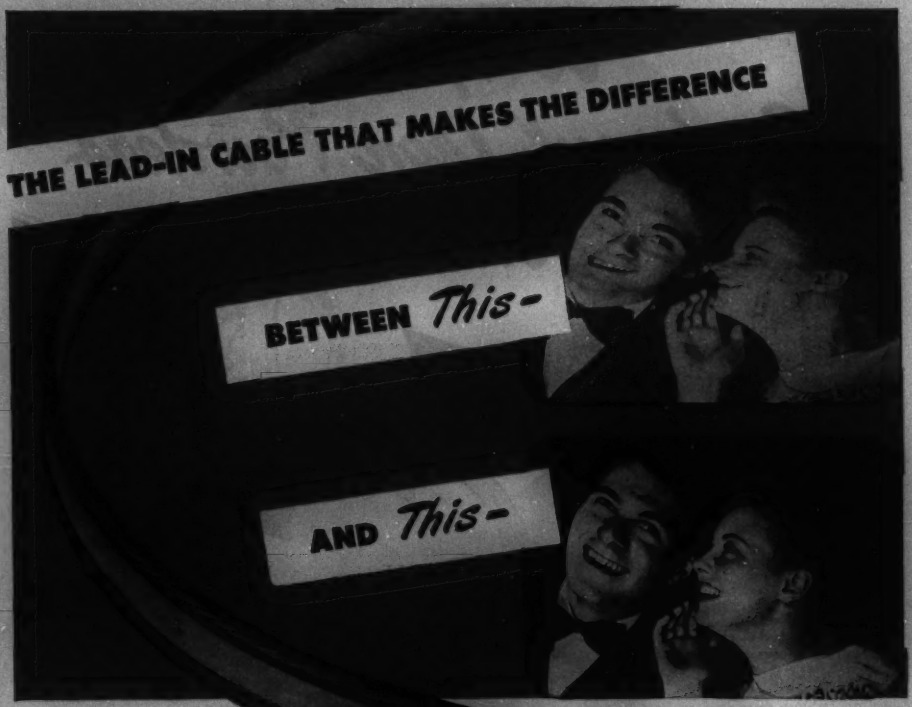

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Du Pont POLYTHENE

With the home television set, much of the attenuation and distortion of images that sometimes occurs on the screen may arise in the lead-in cable from the antenna to the instrument. But not with the new Type ATV cable shown here. With this cable, attenuation is minimized . . . images are strong and clear.

The unusual design of this new lead-in line deserves much credit for its high effectiveness. But note—what makes this design possible is the excellent electrical properties of the insulation, of Du Pont polythene.

Because of polythene's remarkable dielectric strength, a thin coating of it is all that is needed. Polythene's low power factor makes it unusually effective in every type of high-frequency circuit. Credit also polythene's light weight (specific gravity 0.92) and its ability to retain its toughness and flexibility over a wide range of temperatures.

For complete data sheet on polythene, write to E. I. du Pont de Nemours & Co. (Inc.), Plastics Dept., Room 164, Arlington, N. J.

Du Pont manufactures polythene molding powder.

Commercial extruders convert polythene into the form of

Type ATV two-wire polythene-insulated cable, for use as television lead-in line between antenna and receiver, made by Anaconda Wire & Cable Co. (Photo 2.5 times actual size.) This rugged, flexible cable, one of the lightest of its type, has an attenuation of 0.75 db/100 feet, and an impedance of 300 ohms at 50 megacycles.

DU PONT
REG. U.S. PAT. OFF.
Plastics
BETTER THINGS FOR BETTER LIVING
THROUGH CHEMISTRY

Why are Carbonyl Iron Powders better?

IN ILLUSTRATION, note regularity of pattern. This is due to uniform shape, density, size, and purity of each particle.

These factors account for high "Q" value—the combination of maximum magnetic permeability and minimum power loss. This is why carbonyl iron powders are better.

The following text gives a brief, complete outline of G.A.F. Carbonyl Iron Powders for those desiring more information.

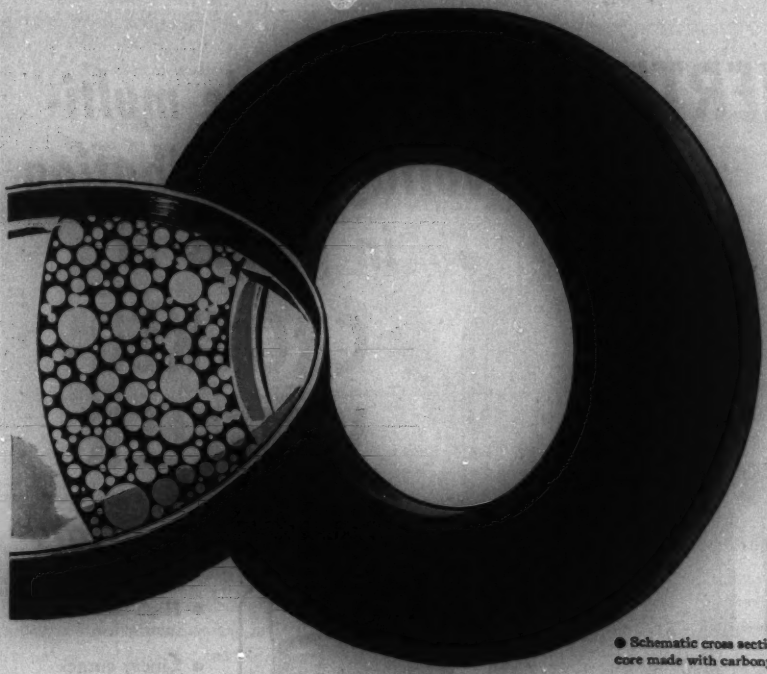
G.A.F. Carbonyl Iron Powders are obtained by thermal decomposition of iron penta-carbonyl. There are five different grades in production, which are designated as "L," "C," "E," "TH," and "SF" Powder. Each of these five types of iron powder is obtained by special process methods and has its special field of application.

The particles making up the powders "E," "TH," and "SF" are spherical with a characteristic structure of increasingly larger shells. The particles of "L" and "C" are made up of homogenous spheres and agglomerates.

The chemical analysis, the weight-average particle size, the "tap density," and the apparent density are given in the following table for the five different grades:

With reference to the chemical analysis shown above it should be noted that spectroscopic analysis shows the rest to be iron with other elements present in traces only.

Carbonyl Iron Powders are primarily useful as electromagnetic material over the entire communication frequency spectrum.



● Schematic cross section of powdered iron core made with carbonyl iron powder.

Table 2 below gives relative Q values (quality factors) and effective permeabilities for the different grades of carbonyl iron powder. The values given in the table are derived from measurements on straight cylindrical cores placed in simple solenoidal coils. Although the data were not obtained at optimum conditions, the Q values as expressed in percentage of the best core give an indication of the useful frequency ranges for the different powder grades.

[redacted]

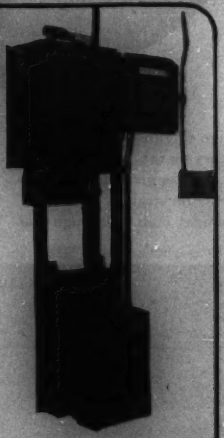
"L" and "C" powders are also used as powder metallurgical material because of their low sintering temperatures, high tensile strengths, and other very desirable qualities. (Sintering begins below 500° C and tensile strengths reach 150,000 psi.)

Further information can be obtained from the Special Products Sales Dept., General Aniline & Film Corporation, 270 Park Avenue, New York 17, N. Y.

G.A.F. CARBONYL IRON POWDERS

AMERTRANS provide multi-voltage distribution in plants of CROCKER-WHEELER

This 750 K.V.A. oil-immersed AmerTran provides general plant distribution at 2300 volts, 3 phase, 60 cycles.



This 37.5 K.V.A. Dry Type AmerTran is a single phase "load center" installation supplying either 115 or 230 volts to Crocker-Wheeler die casting machines.

Among the AmerTran Transformers in the plants of Crocker-Wheeler Electric Manufacturing Company (Division of Joshua Hendy Iron Works) at Ampere, N. J., are the two types shown here.

In ranges between these two types are other AmerTrans, furnishing current at various potentials for required power demands. They are quality products—built with care.

AmerTrans are tailor-made in a plant devoted entirely to the manufacture of transformers and associated equipment.

AMERTRAN ADVANTAGES

- High turn-to-turn insulation
- Linear surge-voltage characteristics
- Fully balanced coil design
- Coils vacuum impregnated
- Rigid, core construction
- Optimum impedance
- "Tailored tanks"
- Electrically brazed connections
- Rust resistant external parts

AMERICAN TRANSFORMER COMPANY
178 Emmet St. • Newark 5, N. J., U. S. A.

AMERTRAN

MANUFACTURING SINCE 1901 AT NEWARK N.J.

Pioneer Manufacturers of Transformers, Reactors and Rectifiers for Electronics and Power Transmission

LABORATORY INSTRUMENTS FOR SPEED AND ACCURACY

HOW -hp- INSURES ACCURACY OF EACH MODEL 400A VACUUM TUBE VOLTMETER

The accuracy of -*hp*- instruments begins with the engineers' blueprints, but it does not stop there. Precision assembly, individual hand calibration for each instrument, and pre-calibration tests over the entire range of the instrument are your assurance that speed and accuracy will be maintained under all operating conditions.

UNIQUE VOLTAGE GENERATOR

Take the -*hp*- Model 400A Vacuum Tube Voltmeter for example. This measuring instrument is unusually versatile, because of its wide frequency range, wide voltage range, and high order of accuracy. For adequate production tests of the 400A, it was necessary to develop known voltages ranging from 3 millivolts to 300 volts, at frequencies from 10 cycles to 1,000,000 cycles. HP engineers solved the problem by building a unique voltage generator which would function as a test set by generating known voltages over the entire range of the Model 400A. Circuits were devised to develop 160 different combinations of voltages and frequencies, each a separate calibration point for the 400A. Each of these voltages is related to the other with an accuracy of better than ½%. The absolute magnitude of each voltage is held to better than ±1%. This voltage is compared regularly with standard laboratory instruments of high accuracy. The voltages which are developed are sinusoidal so that no error in calibration is introduced by poor wave form.

DEPENDABLE ACCURACY

Because of this careful checking and rechecking, you can depend on the operating efficiency and accuracy of the Model 400A Vacuum Tube Voltmeter for many measuring jobs, including measuring voltages in the audio, supersonic, and lower rf regions; amplifier gain; network response; output level; hum level; power circuit, high frequency, video, and carrier current voltages; capacity; and coil figure of merit. An outstanding feature of the -*hp*- Model 400A is that voltage indication is proportional to average value of the full wave.

For complete data on the Model 400A, and on other -*hp*- laboratory instruments, write today to Hewlett-Packard Company.

These -hp- Representatives Are at Your Service

Eastern Representative:
Burlingame Associates, Ltd.
11 Park Place
New York 7, N. Y.—Worth 2-2171

Midwestern Representative:
Alfred Crossley
549 West Randolph Street
Chicago 6, Illinois—State 7444

Western Representative:
Norman B. Neely Enterprises
7422 Melrose Avenue
Hollywood 46, California—Whitney 1147

Canadian Representative:
Atlas Radio Corporation
560 King Street West
Toronto 2, Canada—Wa 4761

1100

HEWLETT-PACKARD COMPANY

BOX 1199A • STATION B • PALO ALTO, CALIFORNIA

Audio Frequency Oscillators *Signal Generators* *Vacuum Tube Voltmeters*
Noise and Distortion Analyzers *Wave Analyzers* *Frequency Meters*
Square Wave Generators *Frequency Standards* *Attenuators* *Electronic Tachometers*

ELECTRONICS

Designer's

LECTROFILM *at a glance*

Lectrofilm is the name of a new synthetic-resin dielectric developed by General Electric Laboratories which combines a greater number of desirable mechanical and electrical properties than any other single capacitor dielectric material. It is admirably suited for use in dry-type, high-voltage capacitors because it—

1. Withstands high and low ambient temperatures
2. Has low power factor and its power factor decreases as temperature rises
3. Has high dielectric strength and constant
4. Is chemically stable
5. Is strong and flexible
6. Has uniform characteristics
7. Is moisture resistant

New High-Voltage CAPACITORS for TELEVISION Pulse Rectifiers

To smooth out the rectified high-voltage power supply in television and similar electronic applications, G.E. has developed a new line of small, light-weight, high-voltage capacitors. These new components are specially designed to meet the exacting restrictions in size and weight made necessary by the compact design of modern television receivers.

Currently available in two widely usable designs —flat cylindrical and long cylindrical—these Lectrofilm* units are equipped with prong-type terminals, designed to meet the special mounting requirements of modern television receivers.

Constructed of thoroughly tested and proved materials, these new Lectrofilm capacitors make available to the television engineer the high quality and reliability demanded by today's television applications. Write for Bulletin GEA-4558.

G-E Lectrofilm capacitors, for use in television pulse rectifiers, are now available in the ratings given in the following table. (Other ratings and designs will be available on request.)

RATINGS AND DATA

Capacitance ratings: all sizes .0005 Mu-f. Capacitance tolerance: plus 3.5 per cent, minus 0 per cent.

Peak Working Voltage	Cat. No.	Maximum R-F Current (Milliamperes) at frequencies of			Net Wt. in Oz.	Approx. Dimensions in Inches	
		30 Kc.	100 Kc.	300 Kc.		Diameter	Length (Inc. terminals)
FLAT CYLINDRICAL UNITS, with Terminals on Axis							
5000	29F201	15	50	150	½	1½	1⅛
7500	29F200	20	75	200	¾	1½	1⅛
10,000	29F196	25	100	300	1½	2½	1⅛
14,000	29F206	30	120	330	4½	2½	3⅛
LONG CYLINDRICAL UNITS, with Terminals on Axis							
5000	29F203	10	40	100	¾	⅞	2⅛
7500	29F204	10	40	100	1	⅞	3
10,000	29F202	10	40	100	1½	⅞	4
14,000	29F205	15	50	125	3	1⅛	5

* General Electric's new synthetic-resin dielectric

Digest

TIMELY HIGHLIGHTS ON G-E COMPONENTS

MORE MAGNET *in less space*

G-E alnico magnets are the answer to many a tough problem in design, where coercive force must be large, and the magnet small.

They are formed by the cast as well as the sintered process which makes possible rapid, large-scale, close-tolerance manufacture of both complex and simple shapes. Compact, with uniform flux distribution and great stability, these mighty midgets facilitate the design of small devices of high precision. Write for Bulletin GEA-3682A.

EVER NEED *a non-linear resistance?*

Frequently, electronic designers need a non-linear resistance to protect against voltage surges, to stabilize power voltages or to control voltage-selective circuits. In Thyrite*, General Electric's silicon-carbide resistance material, current varies as a power of the applied voltage. That is, I varies as E^4.

For example, with a Thyrite resistor whose exponent is 4, doubling the voltage multiplies the current by 2^4 or 16, whereas doubling the voltage applied to a wire-wound resistor merely doubles the current.

Thyrite resistors are supplied in discs or rods, in diameters from 0.25 in. to 6.0 in. Write for Bulletin GEA-4138A.

* Trade-mark Reg. U. S. Pat. Off.

TIGHT, FAST JOINTS *begin with the soldering iron*

With the new line of G-E soldering irons, operators can solder just as fast as the nature of the job permits. Tips stay hot during constant use. The Calrod heating element close to the tip gives a short, low-loss heat path to the work.

Sturdy construction prevents work interruptions due to iron failure. Repairs are infrequent, even under severe conditions. Available in five sizes and types, from 75 to 300 watts, 115 volt or 230 volt. Write for Bulletin GEA-4519.

A LOT OF INSTRUMENT *in a little space*

These thin, internal-pivot panel instruments have high torque, good damping, and a lightweight moving element that withstands vibration. They respond rapidly and accurately. They give you more instrument in less space, because the internal-pivot construction makes the entire element assembly 20 per cent thinner than most outside-pivoted types. Ask for details of the Type DW voltmeter or ammeter—milli, micro, or radio frequency. Bulletin GEA-4064.

REMOTE CONTROLS *that stay in step*

G-E selsyns *stay* synchronized; that is why they are so widely used for remote control and indication applications with single and multiple receivers.

Three sizes of high-accuracy selsyns give operation to within plus or minus 1 degree. Where plus or minus 5 degrees is close enough, use lower cost general-purpose selsyns.

Accuracy values are for 60 cycle, 110 volt operation. Write for Bulletin GEA-2176A.

General Electric Company, Sec. 642-11
Apparatus Dept., Schenectady 5, N. Y.

Please send me

..... GEA-4558 (Electrolim capacitors)	..... GEA-4138A (Thyrite)
..... GEA-3682A (Sintered alnico magnets)	..... GEA-4519 (Soldering irons)
..... GEA-4064 (Panel instruments)	..... GEA-2176A (Selsyns)

NOTE: more data available in Sweets' File for Product Designers

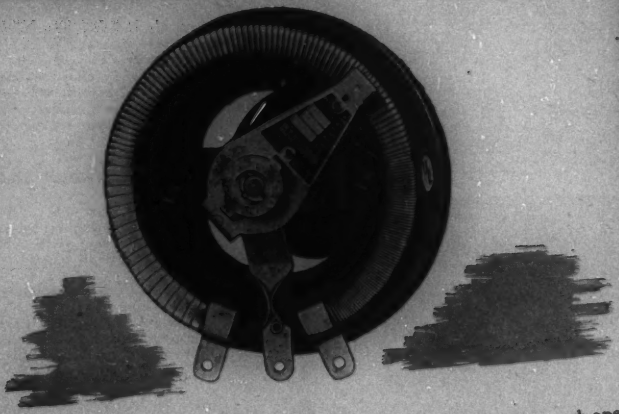
Name .....

Company .....

Address .....

City ..... State .....

Smoother, Closer Control of Generator Voltage with OHMITE Field Rheostats



YOU get exact control *plus* permanently smooth operation . . . in a *compact* unit. The rheostats are tapered or uniformly wire-wound for separately or self excited generators. Continuous variation of resistance in even the smallest sizes saves control-panel space. This saving in space and weight is particularly valuable in portable equipment.

With a series of ten sizes from 25 to 1000 watts available in single or tandem units, there is an Ohmite Field Rheostat suitable for every small or medium size generator. Rheostats designed for special applications. Consult Ohmite engineers on your control problem.

SEND FOR HELPFUL CATALOG NO. 40

Write on company letterhead for this complete Catalog and Engineering Manual. Gives valuable data on rheostats, resistors, tap switches.

OHMITE MANUFACTURING COMPANY

4801 FLOURNOY STREET, CHICAGO 44, U.S.A.

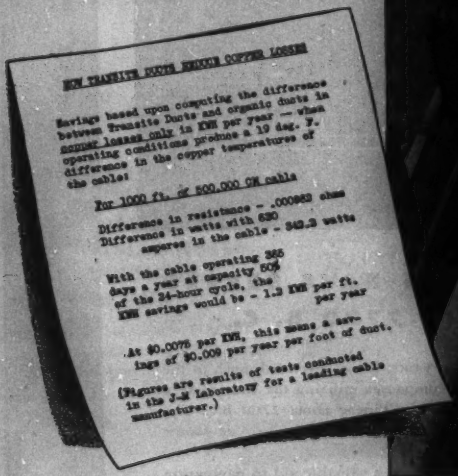
Foremost Manufacturers of Power Rheostats, Resistors, Tap Switches

Be Right with OHMITE

RHEOSTATS • RESISTORS • TAP SWITCHES

Cooler Cables in Transite Ducts mean...

LONGER LIFE *for* POWER LINES


NEW TRANSITE DUCTS REDUCE COPPER LOSSES
Savings based upon computing the difference between Transite Ducts and organic ducts in copper losses only in KWH per year — when operating conditions produce a 19 deg. F. difference in the copper temperatures of the cable:
For 1000 ft. or 500,000 CM cable
Difference in resistance = .000969 ohms
Difference in watts with 620 amperes in the cable = 849.2 watts
With the cable operating 365 days a year at capacity 50% of the 24-hour cycle, the KWH savings would be = 1.2 KWH per ft. per year
At $0.0075 per KWH, this means a savings of $0.009 per year per foot of duct.
(Figures are results of tests conducted in the J-M Laboratory for a leading cable manufacturer.)

High cable temperatures increase cable costs all along the power line!

In Transite Ducts, where cables stay cooler —*reduced copper losses alone* represent a savings of 1.2 KWH per foot per year.

This test case is one of many conducted by Johns-Manville Research Engineers in co-operation with a leading cable manufacturer, proving that Transite Ducts keep cables cooler —dissipate I^2R losses 13% faster than other ductways tested. Copper losses are reduced, insulation life is prolonged . . . and current carrying capacity increases as much as 15%.

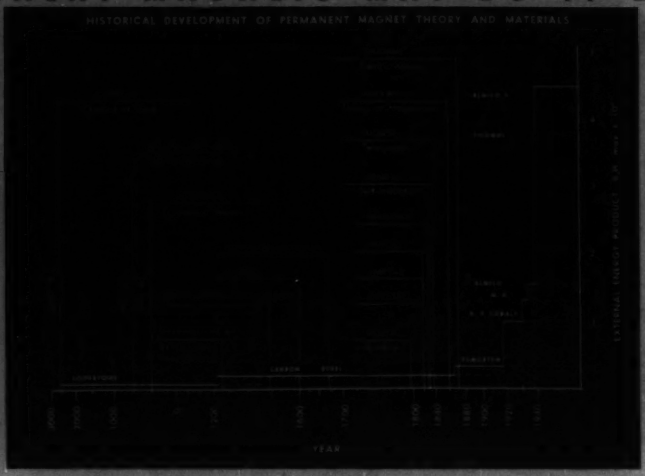
Made of asbestos and cement, Johns-Manville Transite Ducts are strong, immune to rust and rot. They are incombustible and unaffected by electrolysis or galvanic action. A permanently smooth bore makes possible long cable pulls and easy replacements. Long, lightweight lengths can be quickly and economically installed. In addition, a full line of fittings simplifies even the most complicated installations.

For full information write for Data Book DS-410; Johns-Manville, Box 290, New York 16, N. Y.

Johns-Manville

TRANSITE DUCTS
CONDUIT for use without concrete
KORDUCT for concreting in

PERMANENT MAGNETS MAY DO IT BETTER



PERMANENT MAGNETS HAVE SERVED MANKIND SINCE 2700 B. C.

The magnet, one of mankind's oldest servants, has contributed much to the advancement of civilization. Primitive compasses utilizing the lodestone, a crude permanent magnet, were used by the Chinese about 2700 B.C. The term "magnet" is said to have derived from *Magnesia,* a city in Asia Minor where many such lodestones were found.

While the compass using the magnet became a valuable aid to navigation and exploration through the centuries, it was not until the 19th Century that important strides were made in discovering other uses; and only in the last two decades that the powerful alloys were developed from which are made the permanent magnets that serve modern communication, transportation, industry and science in their myriad of diversified uses.

Infinitely more power can now be packaged in smaller, more compact magnet designs with the new high-energy alloy materials—such as Alnico V. More than 24,000 permanent magnet applications have been developed by *The Indiana Steel Products Company,* manufacturers of "Packaged Energy" exclusively for over 35 years. "Packaged Energy" may do some job or process better in your industry. We invite you to consult with our engineers. For data on permanent magnet application, write for "Permanent Magnet Manual," prepared by *The Indiana Steel Products Company.*

Producers of "Packaged Energy"

© 1946, The Indiana Steel Products Co.

THE INDIANA STEEL PRODUCTS COMPANY

6 NORTH MICHIGAN AVENUE, CHICAGO 2, ILLINOIS

SPECIALISTS IN PERMANENT MAGNETS SINCE 1910

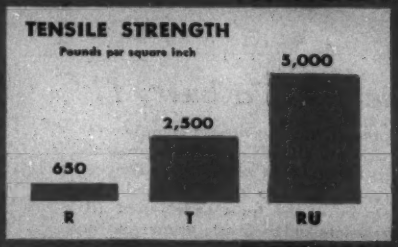
COMPARE Laytex (RU)

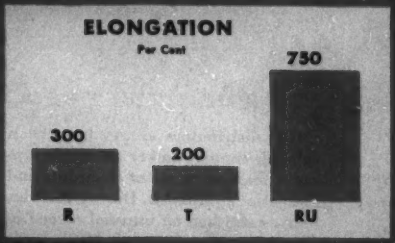
Reg. U. S. Trade Mark

Electrically and Physically

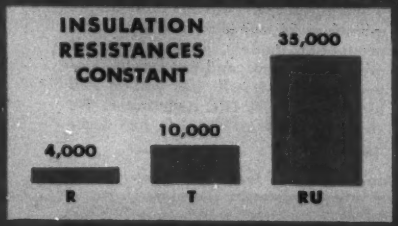
(60° Operation)

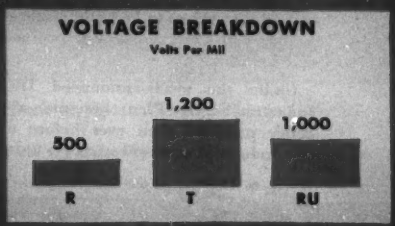
PHYSICAL PROPERTIES





ELECTRICAL PROPERTIES





THREE TYPES of building wire are authorized under the new Electrical Code. These are:

R—Used by the Industry since its inception. The copper conductor has a Code rubber insulation and fibrous overall cover.

T—A copper conductor with VINYLITE (a synthetic compound) insulation.

RU—LAYTEX. This type has a copper conductor, *natural rubber insulation* and fibrous cover.

The charts above show the wide margin by which LAYTEX leads in physical and electrical qualities. This is America's lightest weight, smallest diameter, natural rubber covered wire. *Now available without restriction.*

SERVING THROUGH SCIENCE

Nothing Insulates like Rubber

UNITED STATES RUBBER COMPANY

1230 AVENUE OF THE AMERICAS • ROCKEFELLER CENTER • NEW YORK 20, N. Y.

THE MAN TO KNOW...

JOHN R. SMITH
Authorized IRC Distributor
FIXED AND VARIABLE RESISTORS

. . . when you need resistors in a hurry ! ! !

IRC distributors always have been valuable supplementary sources of supply to manufacturers of electronic and industrial equipment. During the war, they established an unusual record of service to manufacturers. IRC's more than 300 Authorized Distributors have proved themselves to be of the highest caliber, with exceptional organizations and facilities.

Under the newly-announced IRC Industrial Service Plan, these men are better prepared than ever before to give industrial users of resistance units prompt, intelligent and complete service on all IRC standard products, listed in IRC Catalog #50. They are rapidly gearing to maintain adequate stocks of the most widely-used IRC resistors and their sales forces are conversant with electronic requirements.

When you need resistors in moderate quantities for experimental work, pre-production models, pilot runs, small production runs, and for service and maintenance—it will pay you to call upon your local IRC distributor. We shall be glad to furnish his name upon request.

Write to Dept. 5-D for IRC Catalog #50 and names of local IRC Distributors.

PREFERRED FOR PERFORMANCE
IRC
FIXED & VARIABLE RESISTORS

INTERNATIONAL RESISTANCE CO.
401 N. BROAD ST.
PHILADELPHIA 8, PA.
Canadian Licensee:
International Resistance Co., Ltd., Toronto

FOR BETTER-THAN-STANDARD QUALITY... *Standardize on IRC*

While it's very seldom that an overhead line is buried under tons of earth and rock as this one was, yet it's comforting to know that you've selected a conductor that can take this kind of brutal punishment and still carry on!

Upon investigating a current outage in the vicinity of a coal stripping operation in Pennsylvania it was found that a bulldozer had shoved dirt and rocks over the edge of the workings until the two wires on a span of Copperweld-copper conductors had been completely covered and wrapped together.

To put the line back into service, the bulldozer was called upon to cut a valley, as shown in the photograph, allowing the wires to spring back into place. The line was re-energized without requiring repairs of any kind.

Copperweld-copper conductors stand up under gruelling service year after year—that's why you should always specify them on your rural lines.

ALLOY STEEL for STRENGTH
COPPER for LONG LIFE and CONDUCTIVITY

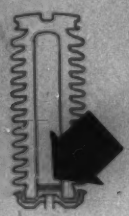
COPPERWELD STEEL COMPANY • Glassport, Pa.
SALES OFFICES IN PRINCIPAL CITIES

Copperweld-copper Conductors

THE DEPENDABLE CONDUCTORS SERVING RURAL AMERICA

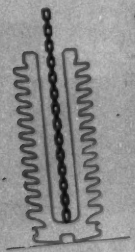
HERE'S THE DOUBLE FACTOR OF SAFETY IN LAPP LINE POSTS AND STATION POSTS

POSITIVE PERMANENT SEAL

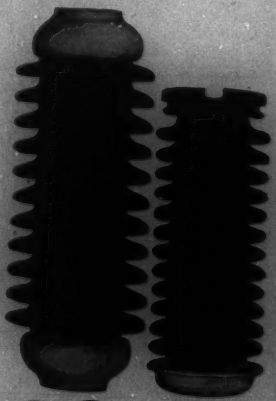


Lapp construction of Post insulators—for line and station use—is proved by a 15-year service record, during which Lapp Posts earned a reputation, *on actual record figures*, for most dependable performance under most difficult operating conditions. One reason is found in the exclusive Lapp construction features. Among these is a *porcelain-and-rubber plug*, inserted at the lower end of the finished porcelain, which permanently seals the interior against moisture.

NO HIDDEN CRACKS OR DEFECTS



The Post design is considered difficult of production because of the likelihood of internal cracks near the head of the insulator. Lapp production technique prevents this possibility. Each unit is fired as an open-end post; it is visibly inspected outside *and in;* and full flashover voltage is applied across the head section. This double factor of safety avoids puncture or flashover failure in Lapp Line Posts and Station Posts—assures dependable, economical performance on your system.



Lapp

LAPP INSULATOR COMPANY, INC., LE ROY, N. Y.

TRUMBULL

INDUSTRIAL POWER DISTRIBUTION

..two suggested Methods..

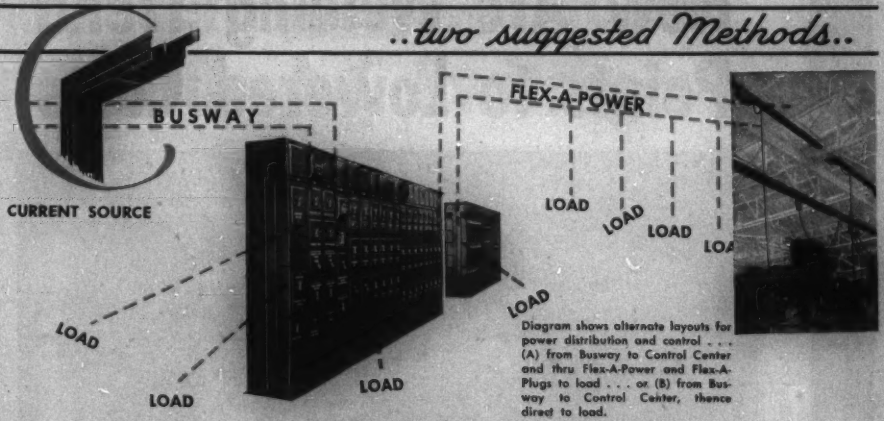


Diagram shows alternate layouts for power distribution and control . . . (A) from Busway to Control Center and thru Flex-A-Power and Flex-A-Plugs to load . . . or (B) from Busway to Control Center, thence direct to load.

THREE PREFERRED PRODUCTS

TRY as hard as you will in planning an Electrical Distribution System and you'll wind up with three preferred products . . .

(1) BUSWAY . . . for your heavy duty electrical highways from transformer secondaries . . . or from main to sub-distribution control points . . . also quite frequently as a medium for interconnection of two switchboards thru a bus-tie breaker. Capacities from 600 to 4000 amperes although 2000 ampere feeders (maximum) are desirable from an economical viewpoint.

(2) FLEX-A-POWER . . . for distribution to loads. The 225 ampere size will be your "best buy".

(3) CONTROL CENTER (preferred over conventional distribution panelboards) . . . which receives its power from (1) and then distributes that power thru (2) . . . or, depending upon type of occupancy, direct to load.

These Trumbull Products are now serving many plants whose names read like a veritable roster of Industry's "Who's Who". You can't go wrong in following suit.

THE TRUMBULL ELECTRIC MANUFACTURING CO.

PLAINVILLE, CONNECTICUT

OTHER FACTORIES AT

NORWOOD, OHIO — LOS ANGELES — SAN FRANCISCO — SEATTLE

A-C'S BULLETIN BOARD

New Arc Welding Trend Points to Lowered Costs

THE ABOVE PICTURE of an Allis-Chalmers electric arc welder being used in fabricating a large compressor cylinder is one example of the growing trend toward use of low-cost arc welding in U. S. heavy industry.

In shipbuilding, fabricating of railroad locomotives, and in many other heavy industry applications, electric arc welding has already won its spurs. Added strength and durability of products, reduced weight, and large savings in production time are some of the advantages it offers over less efficient non-electrical production methods.

Arc welding illustrates how *increased use of electrical power helps industry make things better, quicker, cheaper—furthers American good living.* Allis-Chalmers builds a complete line of electric arc welders for all applications. Write for newest descriptive bulletins.

ON ELECTRICAL POWER

POWER SUPPLY NEWS

Modern OUTDOOR WEATHERPROOF Housing Guards A-C Switchgear

WHAT IT IS: A totally weatherproof, sturdy metal housing encloses every Allis-Chalmers outdoor vertical lift, metalclad switchgear unit—which consists of circuit breakers, primary buses and connections, instrument transformers, meters and relays, ground bus and other secondary equipment.

WHAT IT GIVES YOU:

1) Ventilating openings in the weatherproof housing are covered with non-corrosive metal screens; baffles prevent the entrance of foreign materials and exclude snow and driving rain.

2) Hinged front and rear doors are of ample size to permit easy access to the equipment mounted within the housing. All doors have three-position door stops and latch-type handles, which also allow padlocking of doors in the closed position.

3) Meters, relays and switches are mounted on inside hinged panel, covering the front of the upper compartment within which much of the secondary equipment is located. Thus, all instruments and control devices are well protected, yet are readily accessible when the outer front door is opened.

4) Covers enclosing instrument transformer compartments are easily removed to permit inspection and maintenance of equipment.

5) A space heater is mounted in the secondary compartment, to eliminate condensation within the switchgear unit. Lighting and convenience receptacles are also contained in the switchgear.

Allis-Chalmers outdoor metalclad switchgear is equipped with oil, magnetic air, or air blast circuit breakers, and can be combined with transformers in any desired substation arrangement. For complete details, see our nearby sales office, or write directly to ALLIS-CHALMERS.

A 1937

MULTI-CIRCUIT substation shows typical application of Allis-Chalmers metal-clad switchgear, with outdoor housing.

REMOVAL OF circuit breaker elements from A-C outdoor metal-clad switchgear is facilitated by combination transfer truck.

AC

For table-model, console and large-screen television receivers

RCA now has available four new and improved Kinescopes of standardized type that meet practically all television receiver design requirements. These RCA-developed Kinescopes feature higher quality, longer operating life and far greater brilliance and definition than the prewar types. The use of high-volume precision equipment in their manufacture, coupled with RCA's extensive wartime experience in the design and mass production of cathode-ray tubes is reflected in the lower pricing of all four types.

RCA-5TP4: The RCA-5TP4 (5" face) metallic film Projection Kinescope more than doubles screen brightness of 16" x 20" projected pictures. The "mirror-backed" screen also improves picture contrast and detail. Combined with the Reflective Optical System, the 5TP4 permits viewing at higher ambient light levels.

RCA-10BP4: The RCA-10BP4 with its 10-inch face is the star performer of the directly viewed line of Kinescopes. It is characterized by high definition and picture contrast 2 to 3 times greater than prewar types. Deflection and focus are accomplished magnetically. An outside conductive coating, when grounded, serves as a filter capacitor. The new, high-voltage Duodecal 7-pin base is used.

RCA-7DP4: The RCA-7DP4 Directly Viewed Kinescope is a compact tube with a 7" diameter face particularly adaptable to table-model receivers. It incorporates the same features as the RCA-10BP4 but employs electrostatic focusing and a lower anode potential.

RCA-7GP4: Specifically designed for inexpensive table-model receivers, the 7GP4, also having a 7" face, has exceptionally high deflection sensitivity, a high-efficiency screen and operates at a relatively low anode potential. Both deflection and focusing are accomplished electrostatically. The low-price and high-performance characteristics of the 7GP4 make it unusually attractive for receiver designs aimed at the mass market.

RCA Tube Application Engineers are ready to consult with you now on the adaptation of RCA Preferred Type Kinescopes to your television receiver design requirements. If you wish aid in the application of these or other RCA tube types, write RCA, Commercial Engineering Department, Section D-9D, Harrison, N. J.

COMPARATIVE SPECIFICATIONS

	5TP4	10BP4	7DP4	7DP4
Heater Volts	6.3	6.3	6.3	6.3
Heater Amps	0.6	0.6	0.6	0.6
Anode Volts*	27,000	10,000	8,000	4,000
Focus	Electrostatic	Magnetic	Electrostatic	Electrostatic
Deflection	Magnetic	Magnetic	Magnetic	Electrostatic
Deflection Angle	50°	50°	50°	
Raster Size (approx.)	2 3/8" x 3 5/8	6" x 8"	4" x 5 1/2"	4" x 5 1/2"
Bulb Dia. (max.)	5 1/8"	10 3/8"	7 5/16"	7 1/8"
Length (max.)	12 1/8"	18"	14 7/16"	14 7/8"
Base	Duodecal	Duodecal	Duodecal	Diheptal
Fluorescence	White	White	White	White
Persistence	Medium	Medium	Medium	Medium

*Design center maximum value.

The Fountainhead of Modern Tube Development is RCA

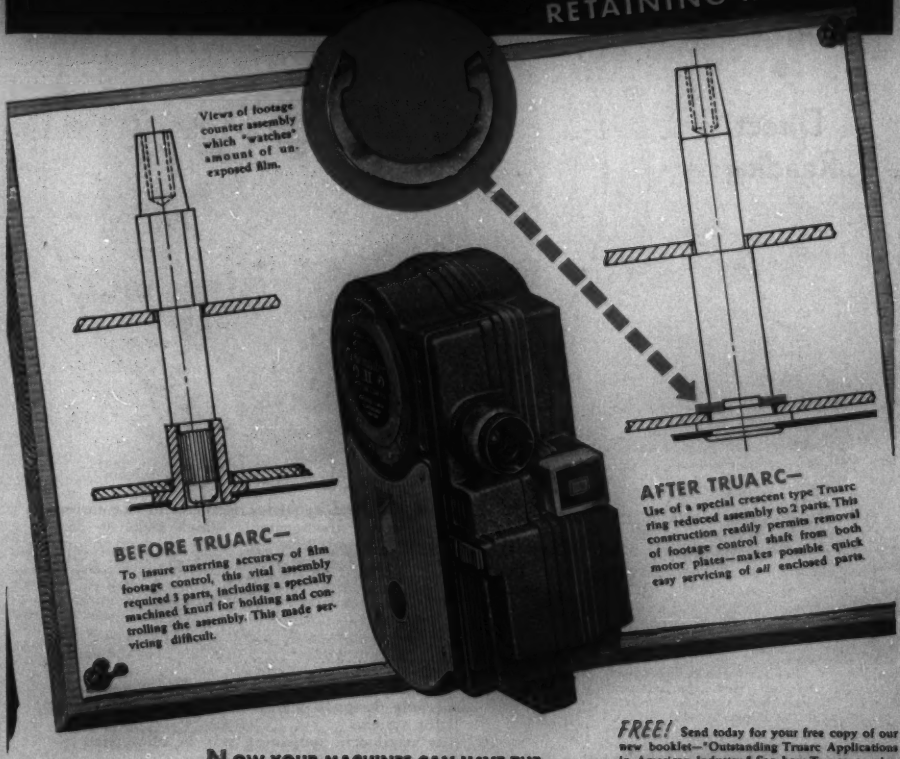
RCA

TUBE DEPARTMENT

RADIO CORPORATION of AMERICA

HARRISON, N. J.

UNIVERSAL CAMERA DESIGN SIMPLIFIED BY TRUARC RETAINING RINGS!


Views of footage counter assembly which "watches" amount of unexposed film.
BEFORE TRUARC—
To insure unerring accuracy of film footage control, this vital assembly required 3 parts, including a specially machined knurl for holding and controlling the assembly. This made servicing difficult.
AFTER TRUARC—
Use of a special crescent type Truarc ring reduced assembly to 2 parts. This construction readily permits removal of footage control shaft from both motor plates—makes possible quick easy servicing of all enclosed parts.

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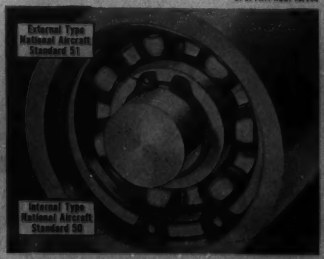

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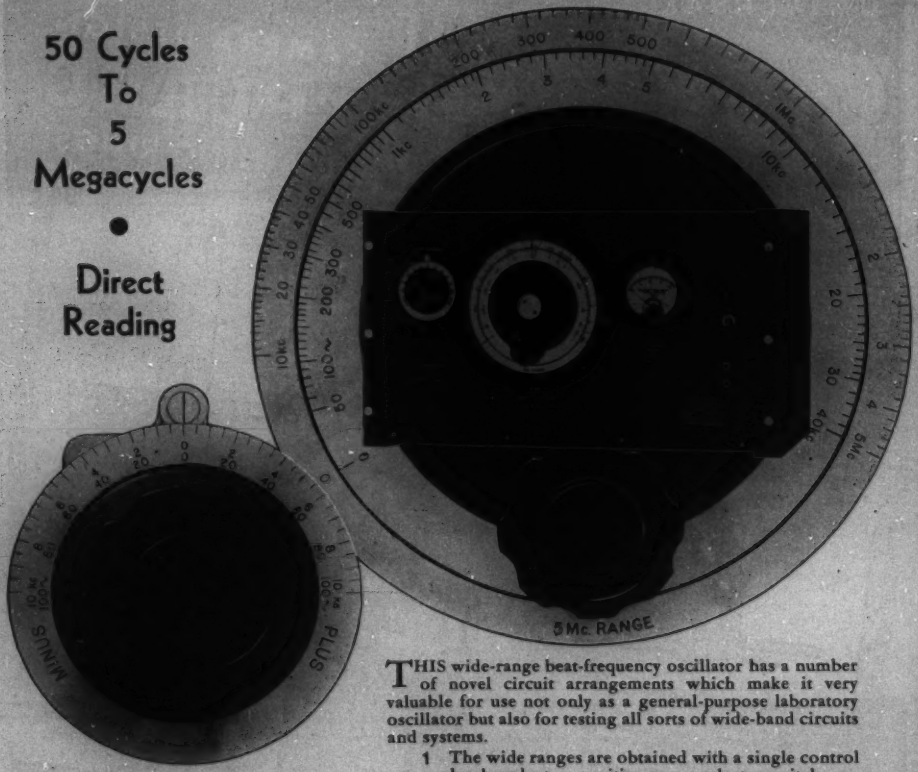

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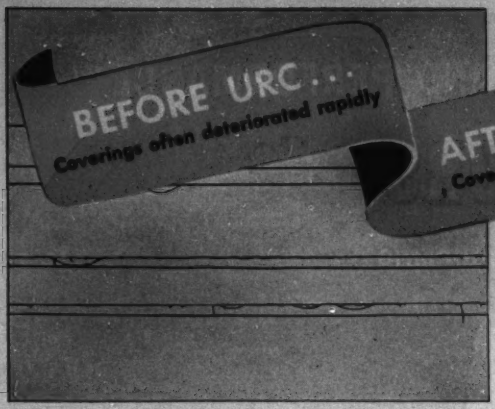

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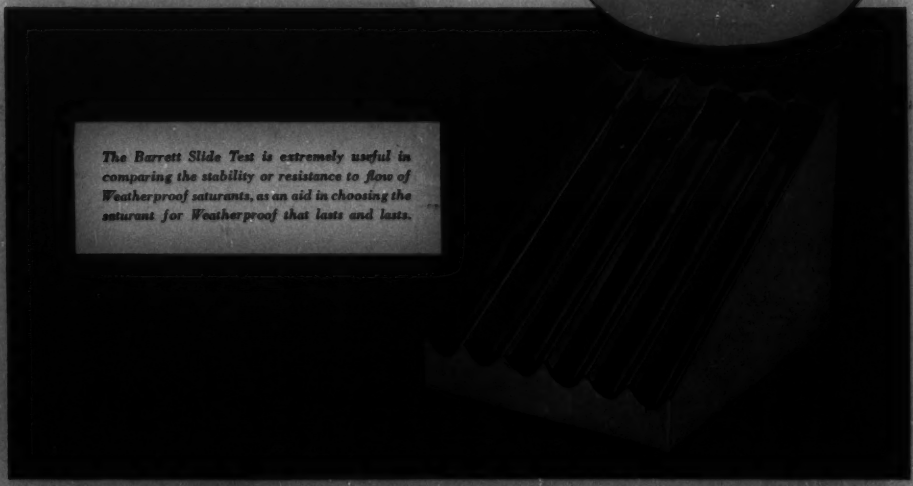
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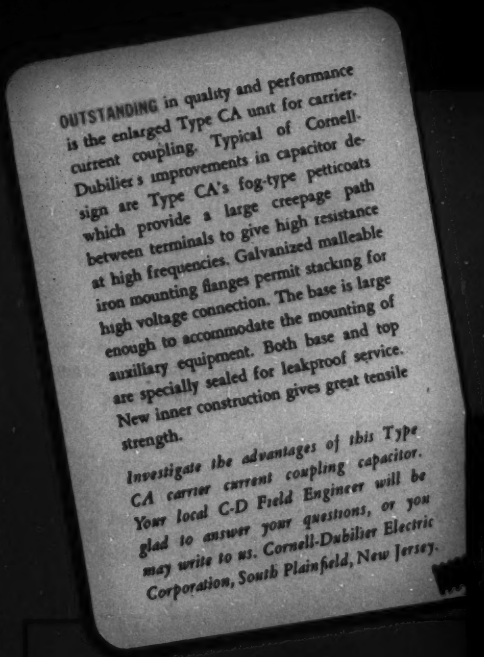
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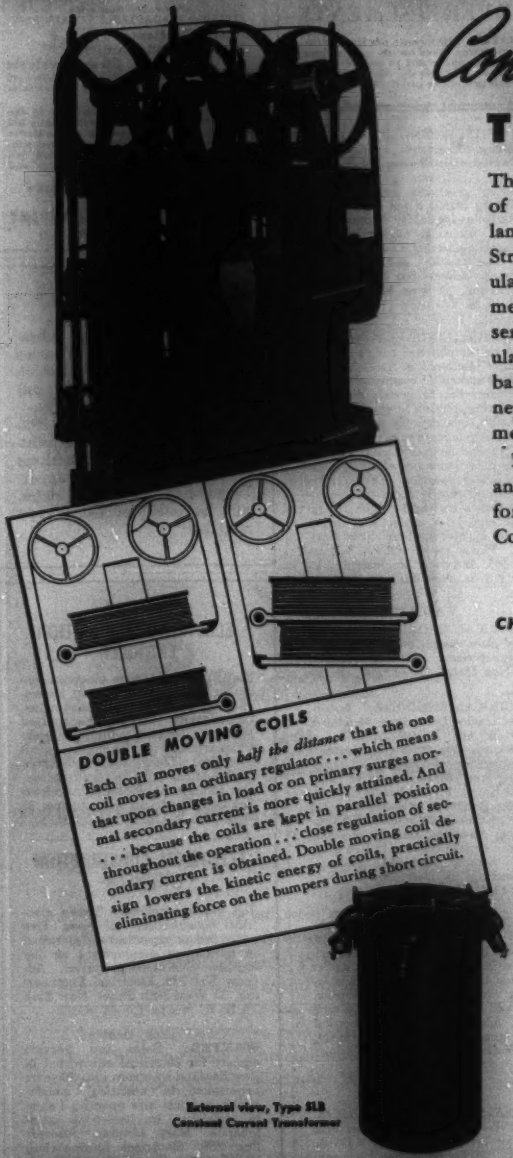

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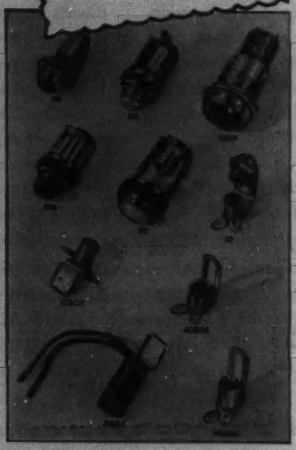

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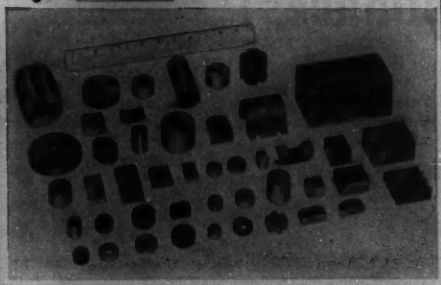

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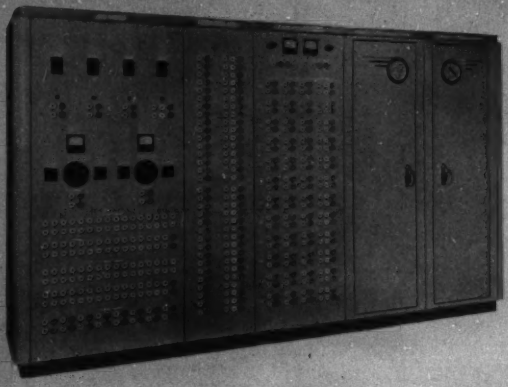

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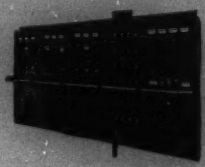

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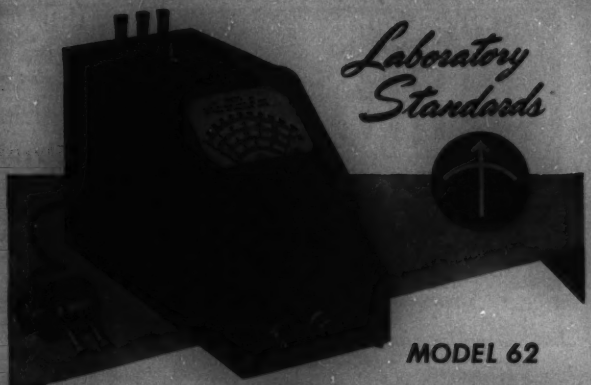

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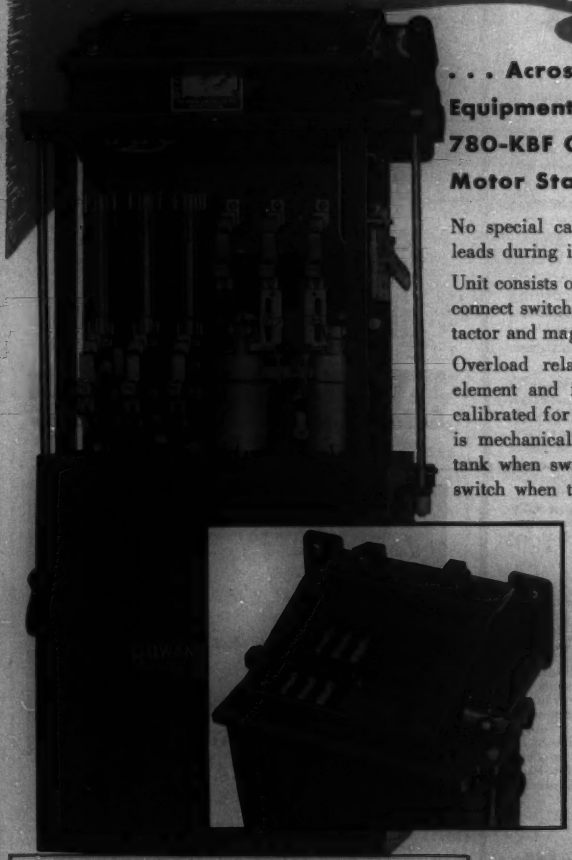

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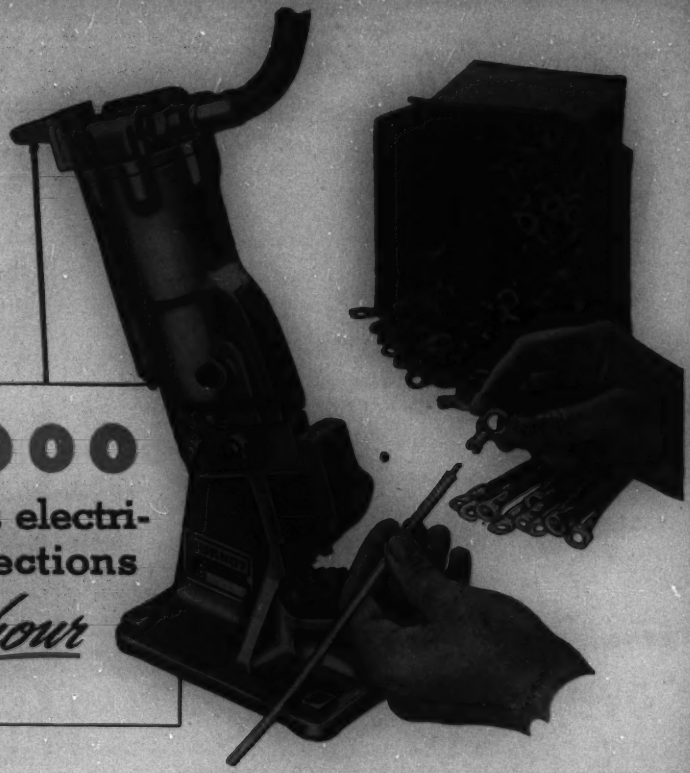

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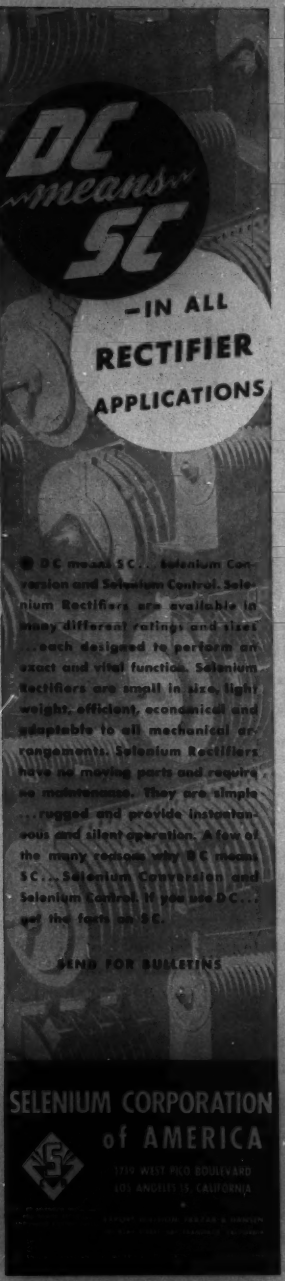
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on 000 to 1,500,000 C.M. cable with
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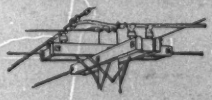
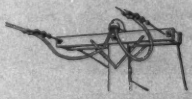
Shows how strain caused by right angle taps can be relieved


Outside Turns, Straight Guys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Hundreds of thousands of these Clamps have been sold.

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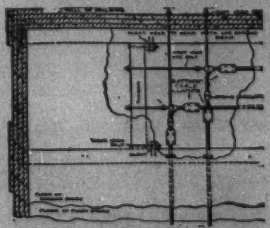
Right Hand Turns in Heavy Cable

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Over the past 30 years we have been a source of supply for precision speed measuring instruments that have consistently demonstrated their superior quality, high accuracy and dependability in service. We now offer a variety of types and ranges of instruments for measuring rotational and surface speeds, and rates of vibration. We believe they will be helpful in the solution of some of your engineering problems. The following are typical:

The FRAHM VIBRATING REED TACHOMETER *requires no contact with the rotating element and is unique for measuring speed of totally enclosed machines and other equipment where the end of the shaft is not accessible. The only mechanism is a set of accurately tuned steel reeds which vibrate by resonance according to the speed of the machine on which the instrument is held. For hand use in servicing, installation and maintenance work; also built in types for permanent mounting. Various ranges available from 900 up to 100,000 rpm. Used also and in the same way for measuring rates of vibration.*

Write for descriptive Bulletin 1590-EE.

JAGABI PRECISION HAND TACHOMETER. *Five ranges in one instrument. Simply rotate the barrel head to change to any one of the five ranges—60-240, 200-800, 600-2400, 2000-8000, 6000-24000 rpm. Measures rpm and fpm by direct pointer deflection . . . fly-ball governor principle . . . large, easy-reading dial with two scales nearly 6¼" long. . . . Accurate to within one scale division. . . . Independent of direction of rotation. . . . Supplied complete with case and accessories.*

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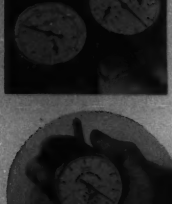

JAGABI HAND TACHOSCOPE. *A combined speed counter and stop watch with synchronized start and stop mechanism for measuring average speeds and constant rates of speed to a high degree of accuracy. Used for routine tests as well as for checking other speed-measuring instruments up to 20,000 rpm. Can be used also for measuring linear or peripheral speeds. Stop watch can be used independently. Supplied complete with case and accessories.*

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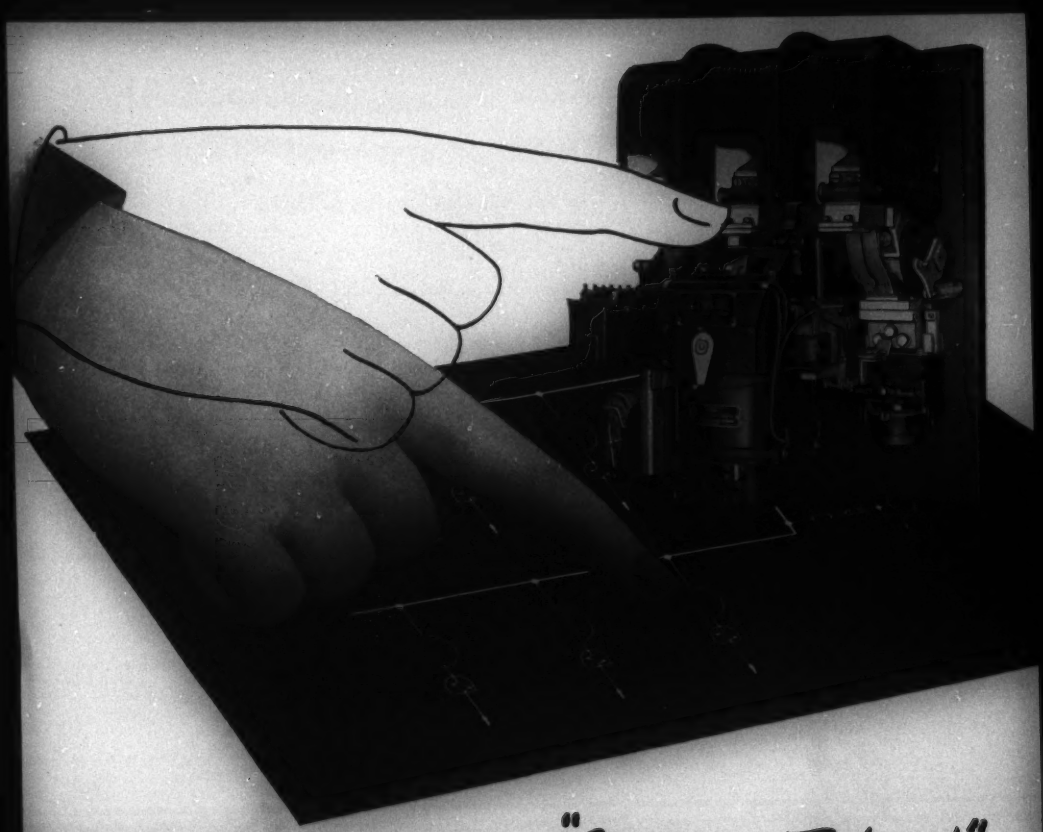

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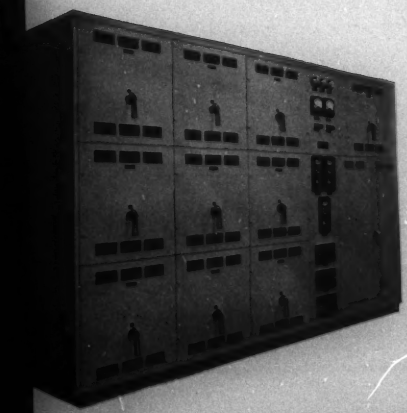

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THE WINNER!

WANTED: 200,000 STARTS

TEST SPECIFICATIONS

TIME ON: ½ sec. — STARTS PER HOUR: 120
LINE VOLTAGE: 118 volts — 60 cycles
RATED CAPACITANCE: 130 — 137MF
STARTS REQUIRED: 200,000

DELIVERED: 1,237,660 STARTS!

...and good for many more!

"Set your own test specifications for our Solar type DX A-C electrolytic motor-starting capacitors," said Solar to a very, very large manufacturer of refrigerator motors. "Make them as stiff as you want and name your own test laboratory."

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